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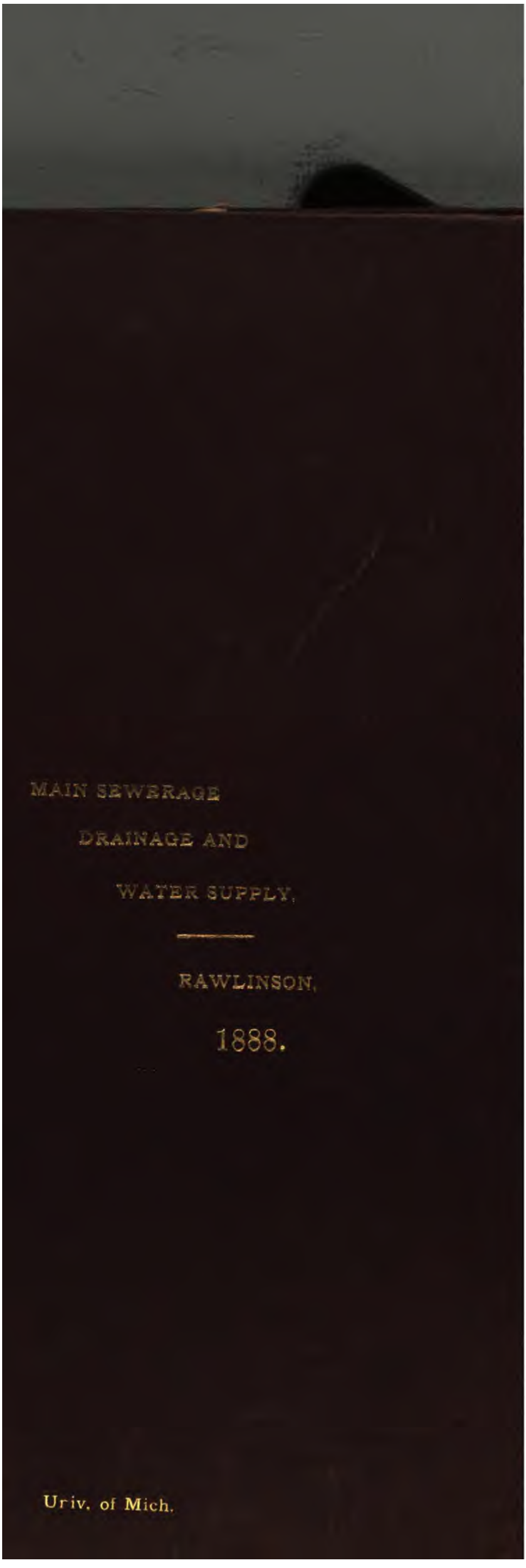

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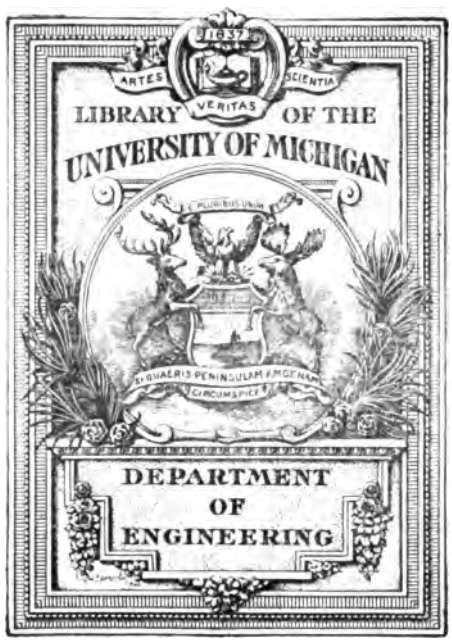
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SUGGESTIONS

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AS TO THE

PREPARATION OF DISTRICT MAPS,

AND OF

PLANS FOR MAIN SEWERAGE,

DRAINAGE, and WATER SUPPLY,

BY

ROBERT RAWLINSON, C.B., Civil Engineer.
(CHIEF ENGINEERING INSPECTOR TO THE LOCAL GOVERNMENT BOARD).

(Revised to 1878.)

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SUGGESTIONS

AS TO THE

PREPARATION OF DISTRICT MAPS,

AND OF

PLANS FOR MAIN SEWERAGE,

DRAINAGE, and WATER SUPPLY.

EXPLANATION of the TERMS used in these SUGGESTIONS.

Sewage.—The fluid and feculent refuse of dwellings.
Sewer.—The main conduit for sewage.
Drain.—The tributary conduit for sewage from houses to sewers.
Sewerage.—A system of sewers.
Raw or Crude Sewage.—Sewage as it flows untreated from a sewer.
Clarified Sewage.—Sewage deprived of solids and flocculent matters.
Purified Sewage.—Sewage filtered through land sufficiently to have neutralized the salts.
Sludge.—The crude refuse from sewage-tanks.
Sewage-manure.—Sludge dried or manipulated to make it more portable, and whether mixed with chemicals or not.
Excreta.—Fœces and urine combined.
Dust.—The ashes and other dry refuse from houses.
The A B C Process.—Sewage treated with alum, blood, clay, &c.
The M and C Process.—Initials of the patentees. The ingredients used are lime, carbon, soda, perchloride of iron, and ashes.
The Pail System.—Moveable vessels placed beneath privy seats prepared to receive excreta.
Soil-pan.—A substitute for a common privy.

In consequence of frequent applications made to the Local Government Board for information relative to Plans to be submitted when sanction is required for loans, and other purposes of the Public Health Act, as well as for information as to the principles to be kept in view in framing plans for works of Main Sewerage and Water Supply, it has been found advisable to issue the following suggestions.

Boundary Map.

In cases in which a Local Government District or a special Drainage District is proposed to be formed, a Map should be submitted, accompanied by a written description of the proposed boundary clearly defined. The description of the boundary should be clear, unmistakeable, and as short as is consistent with accuracy. The name of the proposed district should be on the Map, with the area in acres, the population and the number of houses; the rate of increase as ascertained at the two last decennial periods upon which the census was taken, and a duplicate of the Map, on tracing cloth, should be furnished.

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Map for Division into Wards.

Division into wards is for the purpose of election of members to serve on the Local Board.

A map of the entire district must be submitted, with the main boundary distinctly defined, and the name of the district thereon.

The proposed division into wards must be by lines, clearly defined on the map of the district; brooks, roads, footwalks, streets, fences, or other easily recognisable lines of division of a permanent character may be adopted.

Define such lines on the map by a margin of colour.

Describe the proposed boundary-lines in writing.

State on the map the name or number of each ward.

Give the relative areas, population, and rateable value of each ward.

State the number of members proposed to be elected for each ward.

A duplicate map, on tracing cloth, must be provided by applicants in each case, such tracing to remain with this Office for future reference.

N.B.—Where correct tracings are supplied, it will not be necessary to send up the original plans also.

Plans of proposed Works.

It will, in all cases, be necessary, upon application being made for sanction to a loan for the execution of works, that Plans, (or tracings of the Plans), Sections, Estimates in detail, and Specifications be submitted with the application accompanied by information as to the Population at the two last periods of the taking of the census, the rateable value of the District, and the amount of outstanding loans.

Such Plans or tracings may be used for showing lines of main-sewers, drains, water-pipes, and gas-mains. The lines of main-sewers and drains should have the cross-sectional dimensions of the sewers and their gradients distinctly marked (written and figured) upon them. The dimensions of water and gas-pipes should also be shown in figures, or by writing. (See the specimen Plans 1 and 2.)

N.B.—No general map should be submitted which is drawn to a scale of less than six inches to a mile, except when the inch Ordnance Map is used.

Maps upon which sewerage-works or water-works are to be shown, or for street improvements should be not less than the Ordnance scale of $\frac{1}{2500}$th. (See Drawing No. 1.)

Sections should be drawn to the same horizontal scale, and to a vertical scale of twenty feet to the inch.

As to plans and details in connexion with Provisional Order applications, see Instructions, page 26.

Detailed Plans.

Any detailed Plan for the purposes of house-drainage, paving, the purchase of land, &c. should be constructed to a scale of not less than *ten feet to a mile*, and upon this Plan should be exhibited all houses and other buildings, bench marks, the levels of streets and roads, of cellars, of the sea at high and low tide level, and the summer and flood levels of rivers. Three feet by two feet will be a convenient size for the sheets of this plan. (See specimen Plan No. 2.)

Enlarged detail Plans and Sections of sewers, side-entrances, manholes, sewer-sluices, sluice-valves, water-pipe joints, and similar details, should not be to a scale less than eight feet to one inch; and for some details, four feet to one inch.*

As it may occasionally be desired to carry out works piecemeal, with a view to save the time which would be occupied in the preparation of a complete Plan from actual survey, it will be sufficient, in the first instance, to furnish any available general plan of

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* *Note.*—Details may be drawn to any scale larger than the dimensions named. Engraved or lithographed diagrams, if clear and distinct, will be accepted.

A new plan of any town or district cannot be used for main-sewering, water-supply, gas-supply, pavements, footwalks and other purposes, without spoiling it; consequently it had better be retained as a standard, and be zincographed; there may then be copies for all local purposes. The zinc plates to be the property of the Local Authority.

streets and roads, with the surface levels and those of the deepest cellars, figured in feet and inches, and the proposed scheme of works shown (or sketched) thereon, after which the works can proceed in sections. It should be understood, however, that a complete plan of the entire district must be proceeded with, so that when the works are finished, the sanitary authority, and this Board, may possess a proper record of them.

MAIN SEWERAGE AND DRAINAGE.

Introduction.

Sewering and draining in a rude manner must be as old as the civilisation which associated men in towns; examples of old sewers exist in China and in India. Rome and other of the cities of Italy were sewered, and some of the public buildings were drained, but we have no evidences that entire sites, including streets and houses, were at any period, Roman or pre-Roman, fully and completely sewered; as, even under the ripest period of Greek and Roman civilisation, the cities which have presented examples of the most refined architecture could have been only partially sewered, the cloaca-maxima of Rome being one of the largest examples, and this has been more of a valley-line culvert than a useful main-sewer. If any single city of antiquity had been sewered and drained as English towns are now sewered, the remains of such sewers and drains would have been found, even though the entire site had become one heap of shapeless ruins. As no such remains have been found, it may be concluded that such works never had existence. Fragile Assyrian, Etrurian, Greek, and Roman pottery is found in abundance, with hollow bricks, brick and pipe flues, and some drain-pipes and drains, but not any example of an entire system of sewers and drains. The mediæval cities and towns of Europe knew little of sewers and drains. Land draining and town sewering may therefore be considered modern; the principles are not, however, by any means generally applied. A complete system of sewers and drains will not contaminate houses by sewage-gases, but will regularly and evenly transmit all waste-water and all excreta, hour by hour, and day by day, to the outlet.

Unless there is improvement in cottages, and in house and tenement regulations, sewering a town or a village will only be a partial though an important improvement. Over the whole of Great Britain there are cottages so improperly situated, so small, so wretchedly constructed, and so overcrowded, that sewering the streets effects little improvement in their condition. Many such cottages are on sites below the level of an adjoining road or street, or they are in a swamp, or they are against a bank of earth, or are partially buried in the side of some hill; the rooms have either no floor pavement, only the bare earth, or they have rough stone floors, they are low, having small windows which cannot be opened or are seldom opened, and often the rooms are overcrowded day and night with people. Sewers and drains will not remedy these conditions, which nevertheless are abundant causes of disease to the residents in such houses. Then, again, there are places where sewers have been provided, but the full benefit from them is not attained; either because the houses are not connected with the sewers, or because the house connexions are improperly made, and the sewers are contrived to deliver foul air into houses, or because good sewers are neglected and so become dangerous. A place cannot properly expect to banish those diseases that are related to filth merely by providing sewers; unless at the same time it gets rid of its foul privies and putrid cesspits in which filth is stored, and unless it protects its air and water from pollution by filth. Consequently filth-disease occurring after sewers have been provided is not a reason for blaming the sewers, but for seeing that all stores of filth are removed, that water supplies are kept pure, and that the sewers properly fulfil their object of removing filth. Sanitary appliances cannot be provided once for all and to be then forgotten, without ending in disappointment; unceasing attention to them is wanted to secure the efficiency of their action.

Soil-Pans.—In the early days of sanitary work soil-pans were used as substitutes for privies, and were connected direct from the water-main by an ordinary stool-cock or pull-up handle; these arrangements were thought to be cheap modes, but experience has shown that there are risks of water contamination which ought not to be incurred. The danger arises by the abuse of the soil-pan; as, for instance, filling it with excreta to the brim, and then having the stool-cock or draw-up handle-cock out of repair, or open, and the water-main emptied so as to produce a partial vacuum, when the excreta can be drawn back, and has on some occasions been so drawn back into the water-main so as to cause most offensive and dangerous contamination. Soil-pans can only be used

safely where there is a water-supply through a service-box; or, by having no direct connexion with the water-main; but, being flushed by hand. There are thousands so placed, used, and flushed in London. The soil-pan may however be an efficient and economic substitute for the common privy in villages even where there is no other water-supply than springs, wells, and pumps; the soil-pan being substituted for the privy and being used as a sink, down which all waste-water is thrown, this water being sufficient to flush the soil-pan and to keep it in order. Several villages in Northamptonshire have been sewered, the common privies have been abolished, and soil-pans substituted which are flushed by hand. The inspector of nuisances sees that these soil-pans are kept in order.*

Movable Apparatus.—There are several forms of apparatus substituted for common privies, as dry-earth closets, and movable pails or pans. In each case (in towns) there must be intervention at short intervals to remove, empty, cleanse, and replace the apparatus, or there will be nuisance. Where soil-pans and drains are in use and are properly cared for, the excreta at once flow to the outlet provided, whilst, with a movable apparatus, there is retention of excreta for some period, say from a day to a week, as well as the labour and cost of removal backwards and forwards, the weight of the tub or pail being added to the weight of the excreta. If tubs or pails are neglected by not being removed at the proper time nuisance is caused, which the householder may be powerless to remedy, and where removals are at intervals of a week there may be nuisance in summer occasioned by the smell. In villages where there are gardens to the cottages, the pail or tub can be emptied upon the garden without any secondary intervention, and so avoid this cost.

Suggestions.—The following suggestions are neither elaborate nor in all respects complete, because they are merely intended to indicate to local surveyors some of the leading principles which should be attended to in sewering towns and villages. Main-sewers should remove waste-water from houses and streets to the most appropriate outlet, there to be dealt with by some process which shall render the sewage harmless, The sewers should be at such depth as will effectively drain house-basements, and, when practicable, not less than twice the full diameter of the sewer below basement or cellar floors, to prevent house drains from being back-watered. Drains from basements to sewer should have a clear fall of not less than one in 60, and should enter the sewer by a junction specially provided for the purpose. The utility of sewers will depend upon their proportions and soundness, and these will be influenced by the skill with which they have been apportioned to the work to be performed; and the truth and soundness of their execution. In sewering a town or village the main-sewers should first be completed, side-junctions for branch-drains and house-junctions having in all cases been provided and indicated on the plan. House-drains, in detail, may then be proceeded with.

The safety and comfort of the inhabitants will depend more upon the proper arrangement and perfect construction of house-drains, water-closets, and sinks than upon the main-sewers; but in many cases local authorities after having carefully constructed main-sewers have paid insufficient attention to house-drains, the results being great discomfort, injury to health, and discontent. There is the power, Part 3, Public Health Act, 1875, Section 23, which authorises and enables a local authority to serve notices relative to house-drainage, and at the expiration of the time to undertake the work and do it properly, charging the cost on the owner; builders are, however, frequently permitted to execute works of private drainage without any supervision, which leads to mistakes and to mischief, and, if the house is subsequently drained in a proper manner, to much extra cost.

In some towns, London for instance, a per-centage of house-drains have no connexion with the sewers, and most of the drains are of defective material, the design and the workmanship being worse than the materials. As the drains have no regular invert-fall, and the joints are open and leak, the whole basement being traversed with them, the subsoil is a swamp of sewage; then there are sinks inside cellars and sink-grates on the

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* *Note.*—A use of soil-pans implies a syphon-trap, and is only suggested as a remedy for the common privy. Great care will be required to prevent the seat of the pan being wetted, and the local inspector of nuisances will have to see that the pans are not choked by improper substances or unduly fouled by improper use. The village of Hatherop is entirely supplied by movable tin-pans, each costing 3*s*. The pan is placed beneath a seat on a brick floor; the dry-earth or dry-ashes are put in by hand; each pan is emptied once a week, the contents being placed on the cottager's garden. The gentleman who owns the property has provided the apparatus, and pays for supervision, at a cost not exceeding 2*s*. per week for the entire village. The waste slop-water is passed into drains, being absorbed and evaporated in dry weather; and, with the surface-water, flowing into a watercourse in wet weather. The dry-earth system disposes only of the fæces and part of the urine, so that any such system does not entirely prevent stream pollution.

floors, through which sewage-gases pervade the internal air; the only safe remedy being an entire removal of drains and tainted subsoil, and having an entirely new arrangement of drains by which sewage-gases shall be effectively excluded from the house.

The proper junction of house-drains with sewers should be imperative, and house-drains should always be executed in accordance with a sanctioned plan, the Local Authority insisting, as far as practicable, upon every house-drain being designed, constructed, and carried to the main sewers under the supervision of their surveyor.*

To sewer a town, and then to leave house-drains to hap-hazard construction, is simply little better than to waste the ratepayers' money. Comfort and means for health are only to be secured by the best house-drainage, and the best house-drainage will not be accomplished by builders working under no responsibility.

Town-sites necessarily have surface-drainage, and frequently there are old drains to remove surface and storm-water. If the surface-drains are imperfect they should be improved, so as to be made efficient, as the work of removing heavy falls of rain should not be thrown on new sewers.

Tables of rainfall. The flow of water from land, and the delivering power of sewers or of water-pipes, are not given in these suggestions. Such tables may, however, be found in the late Mr. N. Beardmore's book; as also in other similar works. Hydraulic tables may be of service, but they must be applied under the discrimination of practical knowledge, or they may prove to be more misleading than useful. For main-sewering the engineer may profitably consult tables of rainfall, of areas, and of the flow of water from the site, and it will be quite in order for him to do so; but if he attempts to apportion sewers so as to be of capacity to receive and remove the flood-water, six to ten or more feet below the surface, he will commit a serious and costly blunder, as heavy falls of rain cannot be dealt with in such manner. A rule of three sum, made up of "area, rainfall, and dimensions of sewers," cannot safely be acted upon. Heavy falls of rain must pass at and over the surface as during previous time, or special drains must be used if they exist, or must be provided if they do not exist; and the sewers must be confined in sub-sectional capacity, so as to be equal to the removal of waste-water from houses and manufactures. In large towns there may be exceptions; and then, as in London, flood-water overflow-channels into natural streams may have to be formed. Any town or district which can be sewered effectively, and yet limit the admission of surface-water and exclude subsoil-waters, will, of course, reduce the volume of sewage and so enable it to be more easily dealt with, either by pumping or by gravitating to land for irrigation.

The flow of water from a drainage-area during continued heavy rain, as in a wet season, or during a thunderstorm, may swell the rivers and natural streams so as to swamp sewers and water-log low parts, the sewers will not, however, necessarily be too small nor in fault; as, on examination, it will be self-evident that larger sewers would have been swamped, if such had been formed. Some rivers in England rise vertically in flood as much as 20 feet, or even several feet more; then tides are liable to back-water outlet-sewers, as at Brighton, Portsmouth, Hull, Liverpool, and other towns, as, for instance, those on the Tyne. In some of these cases pumping is resorted to; in other cases the sewage is retained in tanks, or in tank-sewers, until the ebbing of the tide, and no absolute rule can be given when one or the other mode shall or shall not be adopted. Where an outlet sewer is liable to be backwatered, it will be advisable to keep the invert up as much as possible, even at the expense of the gradient, as it will be better to have even a level invert and depend on flushing rather than have an invert backwatered daily, during which period the sewage must be stagnant and must also be depositing silt. Suppose the range of tide is 20 feet vertical, and a main-sewer is taken by a regular gradient from high-water down to low-water level, it must be clear that such a sewer will practically have no fall at high water, and will be impeded during the entire tide.

The sewage of a town or village will consist of waste-water and excreta from the houses, and the volume, in round figures, may range from 100 to 250 gallons per day from each house. This volume will probably flow off in about eight hours, so that the sewers must provide for not less than three times this volume, if even every drop of roof and surface-water can be excluded. As this cannot in all cases be accomplished, the sewers should provide for not less than 1,000 gallons from each house; or, for a town of 1,000 houses, (5,500 population,) have a delivering capacity of about 1,000,000

* No house-drain should ever be joined to a sewer direct, so as to form a continuous flue by which gases may flow into the house. There must be a break in the drain, and means for ventilation so as not to cause nuisance. Sewer and drain ventilation are insisted upon over and over again in these suggestions, because the work is so important and is so generally absent, or even wilfully neglected.

gallons. An outlet-sewer of 2 feet diameter, laid with a fall of 5 feet per mile, will deliver upwards of 2,000,000 gallons, flowing a little more than half full; and as provision should be made for increase of population a sewer of 2 feet diameter may be provided for each 5,500 persons, where no better fall than 1 in 1,000 can be obtained. Lesser diameters will answer where there are greater falls.

A comparatively long line of outlet-sewer may be necessary to intercept and take the sewage of several lines of sewers to some common outlet, where there are sewage-tanks, or " sewage-farms;" this outlet may however be confined to say three times the ordinary flow of sewage, if storm-water overflows can be provided. It will not be desirable to construct the intercepting-sewer of sufficient capacity to remove storm-water, as neither sewage-tanks nor sewage-farm will be enabled to deal with such excessive volumes of water. In some cases it may be practicable to provide a storm-water sewage-tank; this will be where an area of low-lying land may be deep drained, and be embanked, on to which excess of sewage may be discharged at intervals subsequently to filter away. Such an area would be a rough sewage-filter, to be used during wet seasons. A portion of land on the margin of a watercourse may, in some cases, be embanked above flood-level for the purpose indicated.

There cannot be any strict rule by which to ascertain the weight of mud any special town-sewage will deposit during a day, week, month, or year, as the weather necessarily affects the condition of road and street surfaces, and it is (for the most part) from dirty yards and street-surfaces that sewage-mud is derived. A wet season will, as a rule, give from any area more mud than a dry season. The relative weight and character of the mud will also be determined by the character of the street-surfaces, and the weight and rapidity of the traffic. Paved streets produce less mud than macadamised roads, whilst good scavenging prevents excess of mud being washed from any surfaces into and through the drains and sewers. With respect to wear of streets and roads, rapid traffic is destructive, heavy and rapid traffic being most destructive. A good foundation for a road or street is of the first importance, because much of the mud found on pavements has worked up from below. A bottom of concrete will diminish the mud on streets and tend to endurance, and a well-formed road, though more costly to make, will be more cheaply maintained. It will be of great importance to use all proper means to prevent grit and mud being washed into drains and sewers, but it will be a mistake to construct large gulley receptacles, and it will not be admissible to form cesspits on lines of sewer and drain inverts below manholes. The sewers, when true in line and gradient, as also sound in construction, having side-entrances, manholes, and flushing-chambers at proper intervals, will permit of silt being flushed through to the outlet. Large gulleys, having deep cesspits, should only be formed under exceptional circumstances; as in valley-lines, or on main-outlets. For ordinary sewers, and especially for earthenware pipe sewers, small gulleys, having small catchpits, should be adopted; placed at shorter intervals apart so as to be multiplied on the lines of the sewers.

Suggestions.

With a view to convey, in a convenient form, knowledge which has been gathered by experience in sanitary works, the following synoptical information has been drawn up, as being worthy the consideration of local surveyors and others who may be engaged upon such works.

N.B.—Maps not of less scale than ordnance maps (the $\frac{1}{2500}$th scale) may be used for districts and for sewage-farms, the districts and farms being properly defined and coloured. Maps to a larger scale may of course be used. There are repetitions of practical and important rules which are left standing, as it is better to repeat important rules than risk their being overlooked.

Before a scheme of sewerage is devised, the district should be fully examined so as to obtain a correct idea of the drainage-area, or the several drainage-areas; inquiry should then be made to ascertain how surface-water has passed off up to the time of such examination, and with what effects. Main-sewers and drains should be adapted to the town-area, length of streets, number of houses, surface-area of house-yards and roofs, number of street-gullies, and volume of water-supply.

Exceptionally wet subsoils may require special drainage; as, where the sewage may require to be pumped, either for clarification or for sewage irrigation; and, in these cases, the sewers should be water-tight, and the land or subsoil-water must be removed by special and separate drains and arrangements.

The following rules are general; each surveyor must, however, use his own judgment, and make the best arrangements possible, having regard to the circumstances of each special area, and the materials at command:—

1. Natural streams should not be arched over to form main-sewers; because a natural stream may drain a district very much larger than the area built over, and consequently a culvert (or sewer) of capacity to remove flood-waters in a wet season would be comparatively dry during a dry season, and any sewage then flowing in would stagnate and evaporate, causing nuisance. Within some town-areas there are sites, especially on the margins of rivers and streams, liable to be flooded during heavy rain, and if such sites are occupied by buildings, these may be occasionally injured. It may, therefore, be the duty of a Sanitary Authority to decline to sanction plans of buildings, if such are proposed to be placed on sites which cannot be drained, especially if it is intended to excavate cellars. Sewers and drains formed on sites which are liable to be flooded require to be specially protected, the outlets must be provided with valves to prevent floods backwatering the sewers, Plans 17–18; and manholes and lampholes cannot have street surface ventilation openings below the surface flood line; the sewers and drains must therefore be ventilated above this level.
2. Valley lines, natural streams, and surface-areas may be improved, so as to remove more readily surface-water and extreme falls of rain; that is to say, streams filled up by accumulations of refuse may be cleansed and deepened, and areas liable to be flooded may be raised or be protected by embankments. In some districts, steam or other form of power may be required for pumping sewage and ordinary flood-waters, but this pumping power can only be of some moderate capacity, and as there may be (on occasions) extreme floods liable to injure property it will be the duty of the Sanitary Authority to provide, by anticipation, so far as may be practicable against such flooding and injury.
3. Main-sewers must not be of capacity to contain flood-water of the area drained, as such flood-water should be passed over the surface, or by special channels and flood-water drains.
4. Main-sewers should be laid out in straight lines and true gradients, from point to point, with side-entrances, manholes, flushing and ventilating arrangements at each principal change of line and gradient. (See Plates Nos. 1 and 2.) All manholes should be brought up to the surface of the road or street to allow of inspection, and should be finished with a cover easily removable. (See Plate No. 4.) When sewers are laid out in "straight lines," and the surveyor insists upon absolute truth of workmanship both in line and in gradient, the work will necessarily be well done. With manholes and lamp-holes at each change of line or of gradient, the surveyor, by removing the covers, can at any time set out the central line of the sewer upon the surface, and can ascertain the depth from the surface to the sewer at any intermediate point, and so find the exact position of any side-junction. Some surveyors cannot at first see (so as to appreciate) the full advantages of right-line arrangements, and do not find it out until the works have been completed and they wish to form junctions or to examine the sewers for cleansing and flushing, when they discover that the whole of the works, by reason of the manholes and right lines, are fully under inspection and command.
5. Duplicate systems of sewers are seldom required. Existing road-drains and drains to natural streams in valley-lines may be retained for storm-waters, and may be improved; or, if necessary, enlarged. Two sets of main-sewers with two sets of house-drains will be costly to construct; and, if constructed, would often lead to complications tending to defeat the proposed uses. The so-called clean-water-sewer cannot, in many cases, be large enough to receive storm-water, and in dry weather it should of course be dry. The sewer proper would thus be without the flushing and cleansing given by roof water during falls of rain, and the washings off land, ditches, roads, and gutters, during the first falls of heavy rain, would, in many cases, be as polluted and as polluting as the sewage in the true sewer. Again, supposing two sewers in a street, and two

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* Valve-chambers are specially provided at the Waterloo Foundry, Carlisle, to prevent any back flow of sewage in house-drains when sewers are flooded.

sets of drains from each house on each side of such street, the house-drains must interlace the duplicated sewers, the foul-water-drain communicating with one, the surface-water-drain with the other. Under such circumstances it would be almost impossible to prevent builders and workmen from entering the sewers with their drains indiscriminately. Moreover, if the duplicate sewers were not absolutely water-tight, and the subsoil also water-tight, the fluid in one sewer would, by filtration and percolation, act and react upon the other sewer.

6. Earthenware pipes make good sewers and drains up to their capacity. The pipes must however be truly laid, and be securely jointed with cement or with concrete, never with clay. In sandy ground, special means must be used, such as by bedding the joints in concrete. House-drains should, in all cases, be laid in concrete. If the subsoil is porous the trench should be lined with clay-puddle. Special care should be taken to prevent any contamination of wells by sewage when the water from the wells is to be used for domestic purposes. Earthenware-pipes are rarely true in form, as the clay shrinks and becomes distorted in drying and burning, they should therefore be sorted for use so as to form one even line, and in laying, the joint should not bear unevenly in the socket in such manner as to be liable to fracture, but the pipes should bed evenly and solidly in the trench, the sockets being free from pressure, a grip, or small trench, being cut to receive the cement, or the concrete, upon which the joint is to be made.*

7. Brick sewers ought to be formed with bricks moulded to the radii. (See Plate No. 5.)

8. Brick sewers should, in all cases, be set in "hydraulic mortar" or in cement. In no case should any sewer be formed with bricks set dry, to be subsequently grouted. Where half-brick-arches are used the top of such arch should be covered with concrete not less than three inches in depth, and made level over the top of the arch. Half-brick sewer-arches are liable to damage if they are not protected by concrete, as a blow or undue pressure on any part or any joint may force a brick out of place; a covering or bedding of concrete will tend to prevent this form of damage and failure. (See Plate No. 5.)

9. Main-sewers may have flood-water overflows wherever practicable, to prevent such sewers being choked during thunder-storms or heavy rains. An overflow, to be of most use, should permit the sewer to be flowing full, and it should be so situated, formed, and protected, as to relieve the sewer by an opening formed like a bye-wash.

10. Main-sewers should not join at right angles unless the curve and extra fall is provided in the manhole. Tributary sewers should deliver sewage in the direction of the mainflow through the manhole by the invert arrangement. Plan 9.

11. Sewers and drains, at junctions and curves, should have extra fall to compensate for friction. Plan 9.

12. Sewers of unequal sectional diameters should not join with level inverts, but the lesser, or tributary sewer, should have a fall into the main, at least equal to the difference in the sectional diameter. The junctions of sewers and drains should be made with care, so as to permit of the delivery of sewage from side-sewers and drains in such manner as shall not tend to impede the sewage of the main-sewer in its flow. If the inverts of tributary sewers are not above, or, at the least, are not on the level of the ordinary flow of sewage in the main-sewer, such tributary sewers, or drains, will be liable to be back-watered, in which case deposit will take place in the length of submerged invert, and

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* *Note.*—Sanitary sewer-pipes, if more than eighteen inches in diameter, are heavy to handle and difficult to joint, and may cost more than a brick sewer of similar dimensions set in cement and concrete, and not make such sound work. The asphalte-joint makes good work for sewers in wet subsoils, and for house-drains generally. Where it is absolutely necessary to drain houses from back to front, through and beneath the basement, as in streets, the through-drain may, with advantage, be of cast-iron, the joints being made air and water-tight. Proper junctions can be provided for sink and water-closet drainage, and for drain-ventilation. A use of cast-iron for house drains will prevent leakage and subsoil tainting beneath the house, and will be as cheap as drains of earthenware-pipes in many cases. Cast-iron pipes may be used for main sewers with economy and advantage, as where the trench contains quick-sand, or, where the strata is full of water; also in narrow streets where deep trenches have to be excavated. A cast-iron sewer may be two-thirds the diameter of an earthenware pipe or a brick sewer, as the cast-iron pipe may work full and even under pressure.

so the tributary sewer, or drain, will become choked with its own silt. Many drains are so choked where all the inverts in a flat district join upon the same level, because the sewage of the main-sewer, which is in some degree constant, back-waters the inverts of the tributaries as described, which tributaries are only in use intermittently. Plan 7.

13. Earthenware-pipes of equal diameters should not be laid as branches or tributaries, that is, 9 in. leading into 9 in., or 6 in. into 6 in., but a lesser pipe should be joined on to the greater, as 12 in. to 15 in., 9 in. to 12 in., 6 in. to 9 in., and so on. See Diagram No. 12.

14. House-drains should not pass direct from sewers to the inside of houses, but all house-drains should end at an outside wall. House-drains, sink-pipes, and soil-pipes should have ample means of external ventilation. In towns where houses have to be drained from back to front through the basement the drain-pipes should have an effectual joint, and be bedded and covered in concrete, such drains being ventilated, back and front, on the outside of the house.* Flues in walls should not be made into sewer or drain ventilators, and all pipes used as sewer or drain ventilators should be external, the joints should be air-tight, and the top should be taken above the ridge level of the roof. The drain-ventilator should not be less in diameter than four inches.

15. Sinks and water-closets should be against external walls, so that the refuse-water or soil may be discharged into a ventilated trap and drain outside the main-wall. Down-spouts may not be used for ventilation, as the head of such spout may be near a window. Water-closets or sinks fixed within houses, and having no means of direct day-light and external air ventilation, are liable to become nuisances, and may be injurious to health; and if such sinks and water-closets cannot be ventilated in an efficient manner they had better be removed. Water-closet stack-pipes should be formed with solid drawn lead pipes, or with cast-iron pipes having air-tight joints, and each pipe should be carried up at its full diameter through and above the roof to permit of free ventilation.

16. Inlets to all pipe-drains should be properly protected; that is, no pipe-drain should have its upper end exposed so as to admit sticks, stones, or other solid materials being accidentally or mischievously passed in.

17. Side-junctions for house-drains should be provided and be fixed on all new sewers and drains, being part of the contract and the cost included in the contract. During the construction of the sewer the position should be sketched, and indicated by figures in a book or on a plan, and side-junctions not used at once should be carefully closed for subsequent use. If side-junctions are not provided and put in as the sewers are being constructed or laid, the cost of subsequent provision and insertion will be much greater. It will be cheaper to insert extra side-junctions during construction rather than to have pipes to remove, or brick sewers to cut after the trenches have been filled in and become consolidated, and the road or street surfaces made good. (See Drawing No. 4 and No. 9.)

18. Back-drainage may be adopted in many cases with economy and advantage, and if such drains are laid truly in right-lines, from manhole to manhole, any stoppage may be removed or be flushed from such back-drain without inconvenience to any separate owner, because there need be no entrance on private property. See Plan No. 2.

19. A town which is completely and properly sewered will have a system of underground sewage-conduits, formed with even lines and gradients. true in cross-sectional form, and capable of transmitting sewage, at rates of from one mile per hour, to six or seven miles per hour, by flushing. If the town stands upon a site such as Brighton, Bristol, or Liverpool, care should be taken to so plan and execute the main-sewers that the area shall be subdivided by intercepting-sewers, or by "*ramps*" and double ventilation, as at fig. 1, page 12, so as to prevent the lower parts from being flooded with the

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* *Note.*—See note, page 8, as to a use of cast-iron pipes for house-drains. Where drains must pass beneath houses, as in streets, the drain should be effectively ventilated both front and back. At the front, so as to prevent sewage-gas entering the house drain; at the back, so as to liberate sewage gas from the house drain.

downward flow of storm-water-sewage, and the upper parts of the town being injured by the upward flow of sewage-gases. This subdividing the system and intercepting sewage, and specially ventilating main-sewers, will be found to be of the utmost importance, as if sewers are not so dealt with suburban houses, however superior in construction and accommodation, may be poisoned by the transmission of sewage-gases from the lower parts of the town to the higher parts. *See* Plans Nos. 10, 11, 12.

20. A record should be kept by the surveyor of the character of the subsoil opened out in each street as it is being sewered or drained. A sketch-book may be used for the purpose, a section being drawn on a page to show the character and variety of the subsoil as excavated in each street or road, the depths of the various layers, as of sand, gravel, clay, rock, or other material, being described in writing and also figured in the diagram; these books to be indexed, and preserved with the plans for subsequent reference and use.

21. Sewers and drains, as previously stated, should be set out true in line and in gradient. All the materials used should be sound, and the workmanship should be carefully attended to. Surveyors who have had little practical experience in sewer construction, do not at once perceive the necessity for straight lines, true gradients with manholes, or lampholes, at the changes of line or gradient; the reasons will, however, become obvious when works have been completed, as the surveyor will find that truth of line and of gradient can only be obtained by a use of good material and the best of workmanship; the sewer-trench must have been excavated carefully, and must have been shored properly and strongly, the trench must also have been filled in carefully. The side-entrances, manholes, and lampholes on right-line sewers afford means for ready inspection, as also for flushing and cleansing; and, as also previously stated, the line of the sewer can be readily and accurately indicated upon the surface of a street or road, and the exact position and depth of every side-junction be found. In main streets having much traffic "side entrances" may have to be used instead of manholes. Each manhole may be a "*flushing chamber*," (see self-acting flushing apparatus, Plan 18) and each manhole and lamphole may also be a sewer-ventilator. Sewers and drains which have been set out and constructed true in line and in gradient are, for all subsequent time, under the ready inspection of the local surveyor. *See* Plans 1 and 2.

22. "Sight-rails" should be put up in each street before the ground is opened out, showing the centre line of each sewer and depth to the invert. The proper use of sight-rails in sewer and drain construction, when put up by the surveyor, will enable the foreman to set out and excavate the trench truly; these sight-rails should be strong, and should also be securely fixed on firm ground; that is, beyond the influence of the excavation to be made; and if the substratum is peaty or such as will shrink under pumping so as to lower the subsoil-water, care must be taken that the sight-rail or bench-mark to be worked to is in such position as to remain unaffected, or the result will be a crippled sewer; that is, the grade and line will not be true.

23. Sewers, having steep gradients, should have full means for ventilation at the highest points.

24. Tall chimneys may be used, with advantage, for sewer and drain ventilation, if the owners will allow a connexion to be made.

25. Sewer-outlet works should be simple in form, cheap in construction, and so arranged as to remove all solids, sediment, and flocculent matter from the sewage. Under all conditions sewer and drain outlets should be protected by a valve-flap, which will admit of sewage flowing out, and prevent the wind blowing in, and so driving sewage-gases back to the town. *See* Plans, Nos. 10, 13, 14, 17, and 18.

RECAPITULATION.—In executing town sewers and drains danger may be anticipated from several conditions; as, where a street or place is narrow, with buildings on both sides, and where the trench is deep; where the substratum is clay or marl, made ground, loose earth, bog and silt, quicksand, or any combination of such strata.

Quicksand is most difficult to deal with; and, as a rule, such ground should only be opened in short lengths; the trench may require to be close-timbered, and in such case, stable-litter and ashes will be found useful to pack behind and betwixt the "polling-boards." *See* note as to a use of cast-iron pipes, page 8.

In all cases where sewers have to be laid, unless the character of the ground is well known to the depth it is proposed to excavate, trial-holes or trial-borings should be made; and where deep cutting is required (20 feet or upwards), and quicksand is found, it may be best to abandon this line and find some other outlet, or cast-iron-pipes may be used, the trench being entirely filled in with concrete.

Sound looking clay or marl requires careful timbering to prevent heavy breakings from the sides of the trench. When such ground "sets" heavily, the sewer, if of bricks, may be seriously injured; if of earthenware pipes, these may be ruined by cracking or by crushing and distorting the line of sewer or drain-pipes.

As a rule all sewer and drain-trenches in towns should be carefully timbered, and when the ground is loose such timbering must either be left in or be most carefully removed as the trench is filled.

The houses and buildings in narrow streets may require to be propped and stayed; if so, such props and stays ought not to be removed until the sewer or drain has been completed, and the ground has become perfectly consolidated.

N.B.—In many cases it will be cheaper, because safer, to leave timbering in deep trenches, and where there is special danger the trench, as previously stated, should be filled with concrete. Men have lost their lives in sewer trenches which have given way through want of care in timbering and in filling in.

A foreman in charge of sewer-works is expected to be on the watch to see that the men execute the works safely. The local surveyor must see that timber sufficient in quantity and in quality is supplied in time to secure all open-trenches; as, also the buildings on either side.

Where ground is known to be specially dangerous all available precautions must be taken to prevent accidents; the word "accident" should not in fact be allowed.

It is of the utmost importance to impress upon local surveyors the necessity of care in setting out main-sewerage works and house-drains with accuracy, in choosing sound materials, and in properly superintending the works during their progress. House-drains should be so arranged as to be capable of removing all water, soil, and fluid refuse from yards, roofs, and interiors of houses to the sewers, without any risk of gaseous contamination to such houses. See suggestions as to using cast-iron pipes for house-drains. (Page 7.)

Street-sewers should be capable of conveying all sewage to some common outlet, without retaining sediment in them. All sewers and drains should have arrangements for full ventilation, at such points and in such manner as not to cause any nuisance.

If the fluid-sewage can be applied to land for agricultural uses, means should be provided for effecting this purpose.

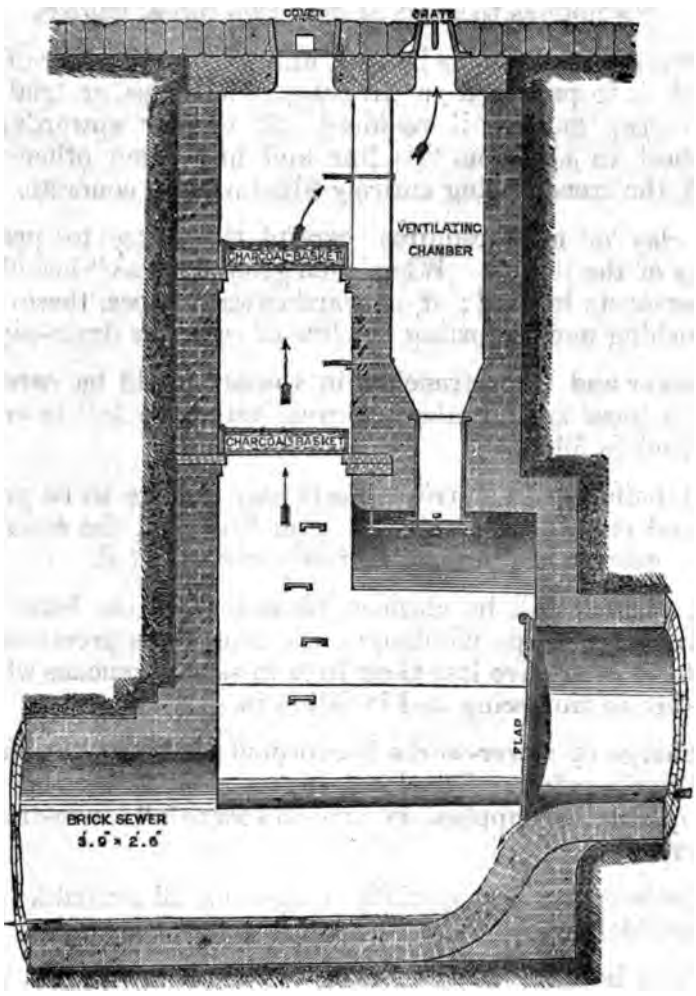
Water-closets should have a daylight window (not a "borrowed light"), and fixed means of ventilation, which cannot be tampered with. Permanent openings, equal to a slit 12 ins. in length and 2 in. wide, should be provided. The cover, or lid of the seat, should be made to close and leave the valve handle free, so that the contents of the closet may be discharged with the lid closed down. At all times when a water-closet is not in use the lid, or cover, should be closed.

Manholes should have movable covers at the surface of the ground; there should be a side-chamber for ventilation, "step-irons" to give access to the invert, and a groove in the invert and sides to allow of a flushing-board being inserted at will for flushing purposes. The side-chamber should be arranged for a charcoal screen or filter. *See* Plans, Nos. 4, 7, 10, 11, 12.

Fig. 1, page 12, exhibits a system of ventilation of sewers which has been successfully brought into use. The figure shows the usual manhole and shaft with moveable iron cover, made to prevent the passage of sewer air. Across the shaft are laid two or more moveable charcoal filtering-screens, through which the sewer-gas, disinfected by the charcoal, passes into a side ventilating chamber and thence through one, or more, open gratings into the street. The chamber is intended to receive any solid matter falling in

from the street, which can be removed when necessary by a slide at the lower end of the chamber. *See* remarks as to charcoal, page 14–15.

Fig. 1.



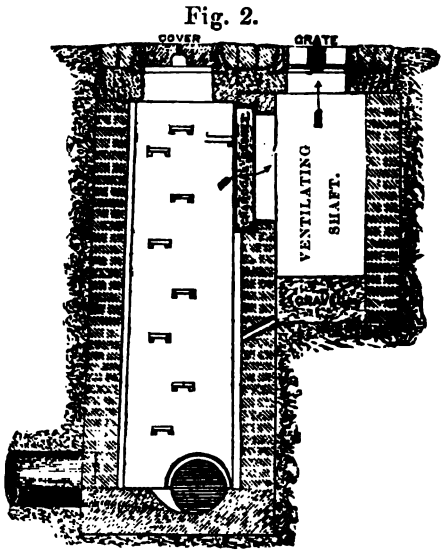
Manhole, Tumbling Bay, and Double Ventilating Arrangement.

The usual method of ventilating pipe drains is shown in Fig. 2, as also Plates 4, 7, 10, 11, 12, where the opening is placed vertically between the manhole and the ventilating shaft.

Earthenware pipes of four inches in diameter are sufficient for water-closets and sinks; these may join drains of six inches, the six inches joining nine inches, 12 inches, and 15 inches, and these forming a tributary main, or passing to a main sewer.*

It is frequently necessary to carry the outlet of a sewer from a sediment-tank or sewage-farm to a river having a low summer level. An iron pipe fixed at the bottom of the sewer with a slight dam in front of the junction will ensure the discharge of all the clarified sewage below the summer low-water level, while the brick sewer above will give free passage to the storm water, and the flap-valve and manhole ventilation will prevent the wind driving any sewage gases backwards.

Fig. 2.



Manhole and Ventilating Shaft.

A sewer, four feet high and three feet wide, may be required for the removal of storm water; while an iron pipe, 12 inches in diameter, would remove all the ordinary flow of water.

* The town of Alnwick, in Northumberland, stands on part of a natural drainage area of 2,000 statute acres, with steep gradients. The population is about 7,000. There is a water supply of 150,000 gallons per day, and some 1,400 water-closets regularly in use. Common privies have been abolished. The outlet sewer is 18 inches in diameter, upwards of 2,000 yards in length, having a fall of one (1) in 400. There are sewers of 15 inches, 12 inches, nine inches, and six inches; all house-drains are four inches. These sewers are entirely of earthenware pipes, and have acted perfectly during more than 20 years. There have been falls of rain, tropical in character, causing great destruction at the surface, but the sewers were not injured, nor did anyone

Fig. 3.

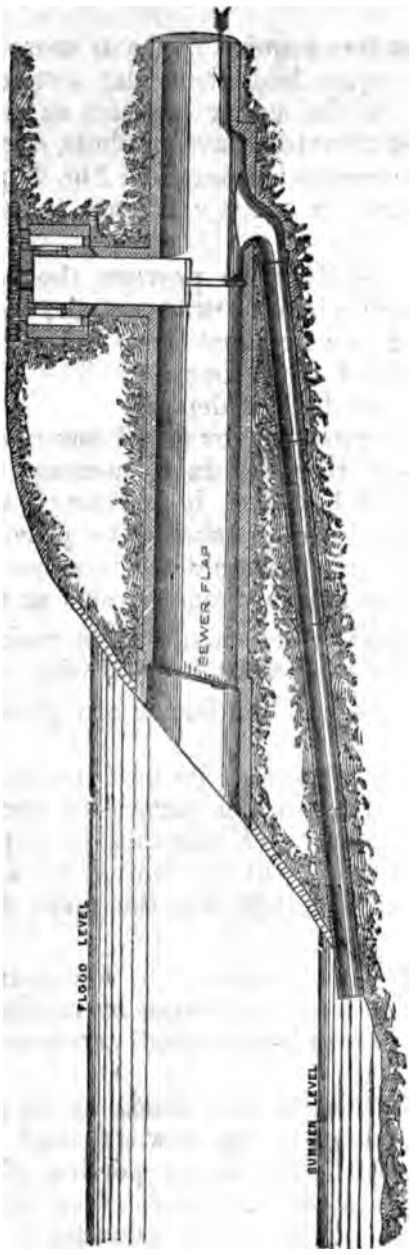
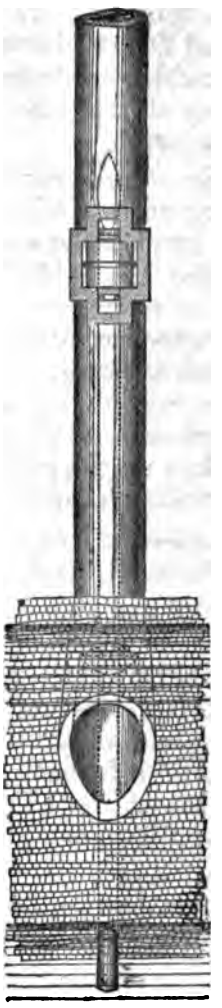


Fig. 4.



Dry Weather River Outlet at Windsor Castle.

Sewer Ventilation.—Towns situate on land rising considerably will best be sewered in zones; that is, by intercepting lines of sewers contouring the site, as such intercepting-sewers will prevent gorging the low-level districts; as, also, prevent the rush of sewage down steep gradients at high velocities, which in times of heavy rain may burst the low-level sewers at the steep gradient junctions. By intercepting lines of sewers, sewage may also, in some cases, be retained at such an elevation as to enable it to be delivered in the country by gravity, on to and over land for agricultural uses. Sewers with steep gradients, if the flow of sewage is unbroken, get up a velocity in the sewage which is liable to be very injurious in its wearing action on the sewers. Sewage should not be allowed (except when flushing is in operation) to acquire a greater velocity at any state or time of more than six feet per second, as any higher velocity will take grit, or other solids, along the sewer invert with a cutting and disintegrating action rapidly destructive to the material of the sewer.

Main-sewers are underground conduits for sewage to flow down, and if they are not fully ventilated at regular intervals along the crown by fixed openings communicating

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complain that sewers and drains of larger dimensions had not been provided. Alnwick Castle is completely sewered and drained by means of one outlet-sewer of earthenware pipe, twelve (12) inches diameter.

Note.—Discredit is brought on both sewers and sewer-ventilation in newly sewered towns where cesspools exist and these are connected so as to overflow or are emptied into the sewers. The refuse is putrid and the stench most offensive. Those who are ignorant of the cause of the nuisance blame the new sewers and desire to block the ventilation. The true remedy will be to abolish the cesspools as quickly as possible, flushing the sewers regularly and abundantly, when the offensive nuisance will cease. A few gallons of putrid cesspool matter flowing into a new sewer, or if emptied into it, will cause more nuisance than the fresh drainage of many houses.

with the external air, they become flues up which sewage-gases will rise and pass through the drains to the connected houses.

Sewers formed along steep gradients therefore require to have more care bestowed on the means for ventilation than other sewers laid along flat districts, to prevent dangerous accumulations of sewage gases in the upper districts of towns. Sewers rising from lower and flatter districts should therefore have manhole, or "*side entrance*" tumbling-bay and double ventilating arrangements as shown in Fig. 1, page 12. This form of tumbling-bay should also be repeated on steep gradients at intervals of not less than 300 yards apart.

Steep gradients in sewers must also be modified to prevent the sewage, during heavy rains, acquiring such a velocity as shall not only wear out the invert, and blow the joints, but also burst the sewers. Earthenware pipe-sewers, when laid down steep gradients, should also be bedded and jointed with concrete. The steps, or ramps, should be so formed as to prevent any accumulation of deposit.

Ordinary main-sewer-ventilation should be provided for on all sewers at intervals not greater than *one hundred yards*, or not fewer than 18 fixed openings for ventilation should exist on each mile of main-sewer. If, however, it is found that some of the ventilators are a nuisance, additional sewer-ventilation should be provided at shorter intervals. Pipes taken up the gable-ends of houses should not be substitutes for street and road surface-ventilation, unless such pipes have a diameter not less than six inches.

The upper or "*dead-ends*" of all sewers and drains should have means provided for full ventilation continued beyond the junction of the last house-drain.

Details for manholes and side chambers for sewer ventilation are given in Drawings Nos. 1 to 13.

Steam-boiler or other furnaces and tall chimneys may be used for sewer ventilation where the owners of factories and of steam engines will permit of such use; but the ordinary means for sewer ventilation must not on this account be dispensed with, as the ventilating effect of a furnace or tall chimney will be limited to a comparatively short length of the sewer, by the number of openings into the main sewers, such as house-drains, street-gulleys, &c.*

Separate costly tall shafts or furnaces for main-sewer and house-drain ventilation cannot be of use in proportion to their cost, as sewers cannot be ventilated as tunnels and coal mines are, in which close airways have to be provided, and are also kept under control.

Sewers liable to be affected by the rise of tides or land floods, as on the seashore, or on a river, must be so arranged that any backing of the sewage shall not injuriously affect the sewers and drains within the town. The lower portion of any system of sewers below the level of high-water of the sea or land-floods of an inland river, must therefore be cut off from the upper portions, and must be so abundantly ventilated that any sewage-gases may be forced out at points specially provided for the purpose, and not be driven inwards and up the steeper sewers of the town through the drains and into the houses. See Plan, Nos. 13 and 14.

The ends of all sewers and drains at the lowest outlets must be so protected that the wind cannot blow in and force any sewage-gases back to the streets and houses. Flap-valves, or other contrivances, may be provided to cover and protect outlet ends of sewers and drains, and so prevent the wind blowing in. See Diagrams Nos. 10, 13, 14, 17, and 18.

Means for full and permanent ventilation of town sewers and house-drains are required to prevent stagnation or concentration of sewage-gases within sewers and drains, and with numerous openings from the sewers to the external air, as described, there will be unceasing motion and interchange betwixt the outer air and the inner sewer air which will bring about and maintain extreme dilution and dispersion of any sewage-gas so soon as generated. It has been found by experiment that in unventilated sewers the gas concentrates, and so becomes deadly,† whilst in fully ventilated sewers the

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* *Note.*—Furnace ventilation of sewers may be dangerous if a damaged gas-main should leak into the sewer, in which case there might be an explosion.

† Men have lost their lives by entering unventilated sewers on some occasions in London, as also in other places.

There are many towns in which the sewers are not ventilated, because the inhabitants refuse to have any open sewer ventilator at the street surface; this is a sad mistake, as a town having unventilated sewers, and house drains connected with them, also unventilated, must have disease in excess.

These paragraphs as to using charcoal are retained, but it must be distinctly understood that a system of sewers properly devised and efficiently constructed, having full and free means for ventilation to the external air, will need no intervention of charcoal, so that a use of charcoal is not recommended.

sewer air is purer than that of some stables, or even than in a crowded public room when occupied. If sewer air at any sewer ventilator or at any other point should be offensive, additional means for ventilation on this sewer are required, and should, as soon as possible, be supplied. Trapping should not be resorted to in such case. It may, however, be practicable to remove such sewer-ventilator to some more convenient point.

If cesspools are required for any purposes they should be made watertight, and be placed as far from wells and dwelling-houses as possible, and should be abundantly ventilated. An open cesspool will be a nuisance, but if fenced in may be comparatively harmless; a covered cesspool must be a source of danger even though ventilated.

Dust-bins should also be fully ventilated.

Ventilation cannot be fully accomplished through single tubes or openings. There should never be less than two passages, or any single tube or pipe must be divided by a diaphragm. Single pipes will ventilate sewers which have numerous openings, but for house-drains there must be inlet as well as outlet pipes or openings to secure ventilation.

Where charcoal is exceptionally used in sewer ventilation it must be understood to retard motion, and provision should be made to meet this:—Charcoal trays, or boxes, for sewer ventilation should never have less than 1,000 square inches of surface exposed for the passage of sewage gas to each 50 square inches of free opening to the outer air. The meshes of a charcoal tray may be about $\frac{1}{8}$th of an inch. The charcoal (wood) may be about the size of coffee beans, clean sifted, and placed in a layer of 2 or 3 inches. Charcoal in a dry state acts best; but its disinfecting property is only diminished by damp: it is not entirely destroyed. The length of the intervals betwixt the renewals of the charcoal will depend upon the dryness of the situation where the material is placed, and the volume and strength of the gas to be acted upon. In some cases two or more charcoal-trays may be used apart, one above the other, so that the gas to be acted upon may have to permeate and pass through the whole of the trays. The charcoal may require in some places to be renewed at intervals of six months. In ordinary sewer-ventilation charcoal need not be used, as the more readily and freely the interchange can be from the sewer or drain to the outer air the better will the ventilation be. Patented sewer ventilators need not be used.

F. For detached houses, villa residences, or larger establishments, drains should never end at the house to be drained, but should be continued beyond and above to some higher point or ventilating shaft where means for full and permanent ventilation can be provided so as effectively to relieve the house from any chance of sewage gas contamination.

Drains for soil and sink refuse should never traverse the basement of any house, but should be external; if, however, there are drains within a basement, and crossing it, such drains should be absolutely air and water-tight within such basement, and should also have full means for permanent ventilation provided outside at both sides of the basement. Pipes of earthenware may be bedded in concrete; in some cases pipes of cast-iron may be used within house basements, as they will be both best and cheapest. *See* note, page 9.

All drains should be laid at the least twice their full diameters below the surface of the subsoil of any basement, and have a fall of not less than 1 in 60 towards the sewer. The full half diameter of the sewer (at least) should be below the junction of the house-drain. *See* Suggestions, pages 6 to 11.

Wherever a trap is placed on a sewer or drain there should also be means for sewer and drain-ventilation provided to relieve such trap, as traps are only safe and useful in conjunction with full and permanent means for sewer-ventilation.

N.B.—It has been suggested that free and open sewer and drain-ventilation will so taint the atmosphere within and over a town as to cause houses at a lower level to pollute those situate at higher levels. Any serious injury from this result need not be feared; as, with the abundant means for ventilation suggested, the air within the sewers (by dilution) will be comparatively pure, and further dilution and dispersion will dissipate every trace of taint and danger, the dilution, through dispersion, being as the cube of the space and the velocity of the air for the time being. The air in one mile of street sewer may be taken at 1,000 cubic yards; the air in the street above at 500,000 cube yards; changed and renewed many times during the day, so that the air in the sewer will be several millions of times less in comparative volume than the air in the street; the dilution of any sewer gas will therefore be in some such proportion.

ARRANGEMENTS FOR FLUSHING.—On a system of sewers every manhole should be a flushing-chamber, so managed as to be charged with water for flushing purposes. There should also be a flushing-chamber at the head of each sewer and drain, and every flushing-chamber should be permanently ventilated. Where there is a public supply of water the flushing-chambers may be filled from the mains, where there is no such public supply they may be filled by water-cart. Flushing a sewer means accumulating water sufficient to pass down and along the sewer below with a rush when suddenly liberated, which water shall loosen and carry away all sediment. Leaving house-taps open, and propping the handles of water-closets will not flush drains and sewers, but will only waste water.* It is possible to injure sewers by overflushing them, and it is therefore the duty of a local surveyor to understand this, and to avoid it.

With sewers in right lines, and even gradients, from manhole to manhole (as directed to be made), the surveyor can first float a light cord from one manhole to the other below, then draw along a stronger rope to which scrubbers may be attached to cleanse effectually such sewers as have very little fall, and are consequently liable to accumulate deposit.

An ordinary amount of subsoil-water may, in some special cases, be admitted into the sewers with advantage, as the regular flow will tend to prevent any silty deposit, and the dilution will tend to lessen the putridity of the sewage. Sewers formed in and along a naturally dry subsoil, if in any degree leaky, are liable to accumulate deposit by allowing the fluids to filter into the subsoil. The trench, in dry and porous subsoils, should therefore be made water-tight before the invert of the sewer is laid in it.

Springs of water, if of considerable volume, may require to be removed from a sewer-trench independently of the sewer, to prevent this surplus water usurping the place of sewage.

Springs of water, and the water from canals, reservoirs, rivers, and streams, may occasionally be so near as to be easily made available for purposes of sewer-flushing. Where this is the case, it will be of great advantage to the local surveyor to arrange for such flushing power being made available.

Sewers and drains perform good service when they permanently lower the subsoil water within a town or near houses. Some sites will, however, require special subsoil drains and subsoil draining.

Sewage Disposal.

The Rivers Pollution Prevention Act, 1876, requires that rivers and streams are not to be polluted by the admission of crude sewage even from existing sewers. There are towns both on the sea shore and on tidal estuaries which do not escape causing a nuisance by discharging crude sewage improperly, the outlets being too near roads, houses, or bathing places. The remedy must be, either to pump the sewage inland for irrigation, or to extend the outlets so that the flow of sewage shall not be returned on to the shore, or to precipitate solids and disinfect the sewage. See Plan No. 14. Inland towns and villages have to deal with their sewage by some of the known processes, the disposal of sewage forming, as it were, part of the cost of scavenging; the cleansing of the old privy and cesspit, as also the dry-earth, and movable pail apparatus devolving where undertaken by the Local Authority upon the same staff as that employed in street scavenging. Towns which are entirely supplied with water-closets and sewers escape, in some degree, the most disagreeable form of scavenging, as the sewage is dealt with in bulk, either to be treated with chemicals and the fluid purified by land filtration; or, the sewage is used in broad irrigation. The cost of any of the processes must be regarded as expenditure of money for cleansing the town; there are in some places natural advantages which tend to diminish the cost, and there are other features in towns which necessarily increase cost.

In some cases sewage will gravitate to the outlet and be at a sufficient elevation to flow over adjoining land, in other cases pumping is required. Where sewage requires to be pumped, it will be advisable to exclude surface-water, and where the gradients will permit of interception, all the sewage above a contour line should be intercepted, so as to reduce the low-level volume to be pumped. Sewage may be retained in tanks to remove the grosser particles; as, also, to retain the flow when on the sea shore or tidal estuary until ebb-tide sets in. Tanks may also be used for clarification purposes where chemicals are used. There has been some wasteful expenditure in tank

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* *Note.*—In some districts watercloset-valves are regularly propped open so as to run the water to waste as it is supposed to sweeten the closet. This is only wasting water to no useful purpose, and in all well-regulated water-works such waste will be punishable by a money fine. Water-closets in which there is a bad stench require ventilation; the house-drain also may require ventilation.

construction, especially in providing for filtering, also in arching over and in roofing. Tanks cannot properly filter sewage; they can only store it for mechanical deposition, and for chemical treatment and deposition, and may therefore be of simple construction and should be open. The area on which they are formed may be enclosed, and then, with ordinary care, there need not be any nuisance injurious to health. All sewage should be disposed of, if practicable, on the day of its production, and the sediment, when emptied from the tanks should be disinfected, and be removed as rapidly as is practicable. Where any manufacture of manure for sale out of the sediment is carried on, care must, of course, be taken to prevent nuisance. The areas which have been found in practice to answer are as under stated, namely, for broad irrigation about one statute acre to each 100 of population of a fully water-closeted town; where tanks separate solids, and the fluid is clarified by chemicals, one acre of land prepared as a land filter may serve for 500 of population, but there cannot be any hard and fast rules as one mode and one area may be successful in one place and may be stated to fail in another place; much will depend upon management. There are several modes of chemically treating sewage which are combined with land filtration; the crude sewage being disinfected, deprived of solids and flocculent matter is first clarified, and then, by being caused to filter through some six feet in depth of land, is purified. These processes enable a much smaller area of land to be available than where broad irrigation is resorted to, as above stated. In some small villages osier-beds are formed on the margins of streams which are prepared and banked, the sewage being caused to flow over the site where it is absorbed in dry weather, and during heavy rain is so much diluted as not to cause any nuisance; the floods in the stream doing no additional injury, the osiers producing some return. Sewage-farm irrigation, to be successful, requires special management, and as a rule it will be better for a Local Authority to let a sewage-farm rather than try to manage by a committee. It is not, however, possible to dictate as to modes of management. One fact with respect to sewage farming ought to be attended to and be stipulated for, namely, that weeds shall be kept down. Sewage will, of course, grow weeds; and, if these are neglected, they will choke other plants. It is indeed objected that sewage fills the land with weeds; it may, however, with more reason be stated that negligent cultivation will permit the land to fill with weeds more rapidly under sewage than in ordinary cultivation, because the land receives more manure. The charge is brought against water-carriage excreta, that houses and towns are tainted by sewage-gases, and that the land of a sewage-farm is deluged and corrupted by sewage irrigation; producing crops which are unwholesome. The reply is, with respect to houses: If any house is injured by sewage-gases the water-closets are improperly placed, the drains are within the house, and neither drains nor water-closets are properly constructed and ventilated. It is practicable to drain a large house and not leave any open drain beneath or within it, and so to arrange and ventilate water-closets as to render any escape of gas within the house impracticable. It is also practicable so to sewer and drain a town that the discharge of sewage shall be continuous from the most distant point on the system to the outlet, that the motion in the sewers shall, at no point, be less than a rate of one mile per hour; and, on moderately steep gradients much quicker. Thousands of houses are so drained, many towns are so sewered.

With respect to the injurious charges brought against sewage farming, inquiry, experiment, and experience disprove them. A sewage-farm need not be turned into a swamp, as one twentieth only of any sewage-farm should as a rule ever be under sewage at one time, and sewage should not be applied more quickly than it is absorbed, the soil acting as a filter, the surface retaining the sediment which is incorporated with the soil, as solid manure is, when the surface is ploughed up. With respect to the produce grown under sewage, or the milk and butter obtained from cows fed on sewage-grass, chemical analyses and continued use prove that both the milk and butter are good in quality. Vegetable produce from a sewage-farm differs in no way from that grown under so-called solid manures, other than by being more abundant, and in some respects better. There are plenty of sewage-farms now in active operation which answer the objections. *See* note below.*

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* 1. Minutes of Information collected in respect of the *Drainage of Land, &c.* (1852).
2. Minutes of Information on the application of sewer water and town manures to *Agricultural purposes*, (1852).
3. Reports of the Royal Commission appointed to inquire into the best mode of distributing the sewage of towns, and applying it to beneficial and profitable uses (1857 to 1865).
4. Sewage Disposal. Report of a Committee appointed by the President of the Local Government Board to inquire into the several modes of treating town sewage (1876).

Up to this date (October 1878) there are about 87 towns, districts, parishes, and places whose sewage is dis-

In preparing land to receive sewage the greatest economy should be used, large open tanks on the land ought not to exist. Costly brick or earthenware carriers need not be made for towns below 10,000, but main carriers can be constructed, in concrete, whilst tributary carriers can be formed with a spade or be ploughed into shape. Main carriers should be in level lengths, as any required fall can be obtained by vertical steps. On some sewage farms more money has been expended per acre in surface forming and levelling than the first cost of the land, in this way more than doubling the rent without giving an equivalent benefit to the land. In some other cases nothing has been done to the land but to bring the sewage and flood it on in a slovenly way—growing weeds rather than grass—both extremes are to be avoided. Crude sewage may be taken to land in cheap conduits, and may be applied direct in thin films from contour grips, so as to flow regularly and evenly on to the land, where it will be absorbed at once without being any cause of nuisance.

Tanking sewage to deposit solids, and straining sewage through material of any sort or under any arrangement of screens, only abstracts the grosser portions of the solids and flocculent matters. Sewage may, however, be deprived of much of its noxious matter in tanks, as also by passing it through what are termed filters, but the fluid remains unpurified, and is only in an improved state to be used in irrigation over heavy land; or to be passed on to a prepared deep drained land-filter; light free soils will receive crude sewage without causing nuisance. The sludge when removed from sewage tanks may have from ninety to ninety-five per cent. of water combined, and from which water it is troublesome to separate the solids, and when they are so separated, in themselves they are worth very little as manure. In some places the solids of sewage are dried at considerable cost to reduce the bulk and weight, and are also fortified by an admixture of chemicals to give manurial strength and value. These details must, however, be obtained from the several patentees. The cleanest and cheapest mode of dealing with sewage is undoubtedly to apply the crude sewage direct, either by gravitation or by pumping, and so at once to distribute it in thin films over the land, the trouble, nuisance, and costs of tanking, screening, and filtering are then avoided, and the land is benefited by having the whole of the fresh sewage, sludge and fluid, incorporated with the land.

Examples of the direct application of crude sewage (sludge and water) may be found at Bedford, Croydon, Chorley in Lancashire, Doncaster, Harrogate, Leamington, Rugby, Wolverhampton, West-Derby, and Wrexham; as also in other places. There are also cheap forms of rude deposition in tanks in some of these places, and in others strainers to separate sticks, rags, and other coarse solids from the pumps, but the crude sewage is pumped direct, without inconvenience, up to 130 feet, as at Leamington, and is passed from the rising main to the irrigating channels for immediate distribution, a little deposit encumbers the edges of some of the first sewage carriers, but this is ploughed in when the land is broken up for fresh cropping. One notable result takes place during the summer and dry weather generally, namely, that only a fractional portion of filtered water is ever found to flow out of the subsoil or drains of a sewage farm, and this water is transparent, colourless, and free from sewage smell. On the Doncaster sewage farm during summer, some 600,000 gallons of sewage are pumped and distributed over from two to five acres of land daily, all of which water is absorbed and evaporated. At Coventry and at Aylesbury the sewage is tanked, treated with chemicals, manipulated into manure, and a clear and clarified effluent is produced. At Coventry the effluent is filtered through a small area of prepared land, and it is reasonable to expect that final land filtering will be advisable in all cases where sewage is treated by chemicals and deposition in tanks.

It is persistently urged by some parties that fluid sewage corrupts the soil over which it is spread, and produces malaria in the atmosphere over a sewage farm. But as conveying excreta in water does not increase it, there may be a difficulty in proving that wet manure, similar in bulk and weight to dry manure, will tend to do more injury to the land than solid dry manure, which, to be of use, must be washed into the land by rain. The facts are, that continued irrigation with foul corrupt sewage in excessive volume for very many years, as at the Cragintinney meadows near Edinburgh, has failed to produce a sewage-swamp, to corrupt the soil, or to produce

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posed of by Irrigation. There are 23 towns, districts, or parishes, whose sewage is disposed of by Precipitation, treatment with chemicals, and partial land-filtration. There are 24 towns, districts, or parishes whose sewage is disposed of by ruder and more imperfect modes of Filtration, as through charcoal, wickerwork, and straw. There are 16 towns, districts, or parishes whose sewage is disposed of by mechanical Subsidence (only). These lists are being added to as sewerage works are executed.

malaria injurious to health; as see the Sewage Report. If sewage produces any of the evils charged against it there must be gross neglect and mismanagement.

Many local authorities find great difficulty in procuring land for a sewage farm on account of the prejudices raised against sewage irrigation, or in consequence of the high price demanded for the land.

In densely populated manufacturing districts there are other difficulties to be contended with besides that of not being enabled to obtain land at a reasonable rate; a sufficient area of suitable land may not be obtainable at any price; and again, the abstraction and loss of dirty water might stop some trades unless equivalent volumes of clean water could at the same time be brought in; this is, however, a purely local question and must be met and be provided for locally. Some of the best forms of chemical treatment combined with concentrated land filtration may have to serve for exceptionally crowded districts, though such processes may be more costly and not so complete as sewage irrigation.

The best land for a sewage farm will have a free loamy soil and open subsoil; the surface will be tolerably even, having a southern aspect gently sloping to the south.

Clay land will require deep draining and to have the surface well broken up, either by spade labour or by deep steam-ploughing; the drains must be so laid and protected as to remove subsoil-water after filtration, and not unfiltered surface-water or sewage through cracks direct to the drains.

Every area, however rough or uneven, may have level contour lines set out over its entire surface, so that by forming conduits on these contour lines the surface may be irrigated. It will not therefore be necessary to spend large sums of money to lay a sewage farm out like a bowling-green.

Land having an irregular and steeply sloping surface may have sewage intercepting drains and carriers so arranged as to intercept the sewage from the upper areas and bring it over the lower areas a second or a third time, by such means more effectively purifying the sewage.

Roads over a sewage farm should, where practicable, be along the fences; costly permanent roads are not required.

When land has been properly prepared for the reception of sewage, it may be irrigated in all weathers so as to purify the sewage.

A wet season does not necessarily injure a sewage farm if the means of removing and consuming the produce are equal to the growth of the crops.

One gallon of sewage weighs 10 lbs.; 224 gallons, or 2,240 lbs., are one ton; 22,400 gallons, or 224,000 lbs., are 100 tons—equal to one inch in depth over one acre of land. Ten inches equals 1,000 tons, and 12,000 tons per acre per annum equals 120 inches in depth, and this volume may be used on well prepared land without swamping it, as land will filter several inches in depth per day when the sewage is equally and evenly distributed.

Italian rye grass will dispose of most sewage and give heavy crops if the roots are young. The greatest producing power will be in the first year's growth. A second year is probably the utmost length of time it should be in the ground.

No larger area of Italian rye grass should be sown than the grass upon it can be disposed of in the district, as it will not keep nor bear distant carriage. Sewage grown grass will make good and wholesome hay if the season will permit, or if the grass can be artificially dried.

To give a sewage farm the chance of paying the land must be obtained at a reasonable price and the costs of preparation must be moderate; there must also be reasonable skill in cropping, in cultivation, and in management, under which conditions land irrigated with sewage ought to pay a reasonable rent. If steam power has to be used for pumping the sewage, this of course must be paid for in addition.

Sewage has been valued as a manure at from $\frac{1}{2}d.$ to $2d.$ per ton. The same sewage will, however, be worth $2d.$ in a dry summer, which may not be worth more than one halfpenny to the farmer in a wet season and through the winter. In practice these prices frequently cannot be realised, not because the elements of value are not in the sewage, but because of the extreme dilution and the difficulty of uniform and equal manipulation, sewage, as a rule, being flooded on to the land in volumes far too large for any crop to assimilate. If from one to three thousand tons per acre of rich sewage could be equally and evenly distributed over Italian rye grass (as by hose and jet) just as it was required, an approach towards the full value of the sewage would be obtained.

WATER SUPPLY.

Pure water is a better solvent and cleanser than hard-water, and for washing is therefore more economical. For most trade purposes soft-water is also preferable, it is better and safer for all steam-boiler uses, as there is less of deposit to "*furr*" the insides of boilers. The source of soft-water is the salt ocean, evaporation and condensation from the atmosphere being the producing powers. The olden geological formations, such as granite, clay-slate, millstone-grit, and similar strata yield soft-waters; limestone, coal-measures, new red sandstone, and chalk, as a rule, yield hard-waters. Wells sunk in any of the strata give the peculiar water of the strata, so much so that a chemist who has studied this form of analysis will indicate the sort of water any geological formation will yield; and by an analysis of any sample of water will also indicate the formation it has been drawn from. Some deep wells, however, yield exceptionally soft and pure water when the water flows from fissures, and is not filtered through the substance of the rock.

There are ruins of vast works for storing and for transmitting water in India, in Italy, and even in America. It is a mistake to assert that the Romans built their grand aqueducts because they did not fully understand the laws of hydraulics. The proof that these laws were fully understood, and were reduced to practice, is to be found in their syphons and in fountains. The modern engineer can use cast-iron and wrought-iron for water-conduits so as to supersede aqueducts of stone. Over the area of India there are thousands of impounding reservoirs and tanks, some in ruins, which have been of enormous capacity, others are in use to this day. Tanks and wells were formed at the earliest periods of history; tanks, wells, and reservoirs are constructed now, both for irrigation purposes and for domestic uses. The great modern improvement in water-supply is the delivery by constant service, and at high-pressure, over the entire area of a town, and into every house, cottage and tenement.

The general principles of water-supply may be stated briefly as follows:—

1. To select the purest available source after careful analysis.
2. To filter the water, if necessary, in order to free it from suspended matter and from dissolved organic matter.
3. To store it in covered tanks, and to raise it a sufficient height for distribution by gravitation. *See* Plan No. 15.

Applying these principles water may be obtained—

From mountain ranges which act as condensers.
„ rivers and streams.
„ natural springs.
„ wells artificially formed.
„ impounding reservoirs.
„ a combination of two or more of the sources named.

And may be conveyed for distribution,—

By means of open conduits (before filtration).
By „ „ covered conduits, always *after filtration*.
By „ „ cast-iron pipes under pressure.

Where a district is to be supplied with water, all other things being equal, the softest and purest water should be adopted.

A water-supply may be gravitating; or, the water may be pumped by steam-power. The relative economy of one or the other form of works will depend on details of cost and quality of water. As a rule, gravitating works require the largest capital. The annual working expenses of a pumping scheme may, however, be greatest.

Reservoirs, for service distribution, should be covered.

If filters are used the water should not be exposed in open reservoirs and tanks after filtration.

Cast-iron pipes, properly varnished, should be used for street-mains. It is not advisable to use mains less in internal diameter than three inches.

Lead should not be used with soft-water, either in service pipes or in cisterns. Wrought-iron tubes with screw joints may be used for house-service. All house-taps should have screw-joints, and be of the description known as "*screw-down*," so as to admit of easy repairs.

In jointing and fixing wrought-iron service-pipes care should be taken to insert double screw-joints at convenient points, to allow of the removal of a length of pipe for alteration and repairs.

Wrought-iron service-pipes are cheaper, stronger, and more easily fitted than service-pipes of lead. Certain sorts of made ground, in towns, act rapidly and injuriously on both lead and iron pipes, such as furnace-ashes, waste from gasworks, and chemical-refuse, old building refuse containing lime. Pipes should not be laid in such material without a lining of sand or puddle, or other special protection.*

Earthenware pipes may be used for water-conduits, provided the joints are not placed under pressure.

Aqueducts of iron will, probably, be cheaper than masonry or brick-work constructions.

Water may be brought in by gravity, that is, water obtained at a distance may be found at such an elevation above the district to be supplied as to allow of its flowing through conduits or pipes to the tanks or cisterns from which it is to be distributed. A fall of 5 feet per mile is sufficient for a conduit of 2 feet diameter. Conduits of larger diameters may have less fall, down to 6 inches per mile, as on the New River, London.

Well-water will vary in purity according to the nature and the soluble matters contained in the ground from which the well derives its supply.

Shallow wells are liable to pollution from matter in the surface soil. Deep wells only, *i.e.*, wells of a sufficient depth to afford water of the requisite purity, should be sunk; and the surface soil water should be cut off from the deep water by casing the well above by cylinders of iron, or by puddle, or by concrete.

Salt rock is found in the new red sandstone formation. There is risk in deep sinking from this cause; but good water is frequently found in the new red sandstone.

A spring is a low point or lip of an underground reservoir of water in the stratification. A well sunk in such strata will most probably furnish, besides the volume of the spring, an additional supply of water if the well or bore-hole is within the basin.

Natural springs may be utilised by storing the water in a reservoir which will contain the flow of one entire day, or longer period, such reservoir to be at sufficient elevation.

Reservoirs should be walled with masonry or with brick, or be of concrete, and may be covered in to protect the water from contamination.

Springs of water at a distance may be conducted in channels contouring the intervening distance; or in pipes of iron or of earthenware.

The fall for a conduit may vary according to circumstances. The fall of the New River is about one in 10,000, small conduits may have intermediate falls, not however exceeding one in 300, unless cast-iron pipe conduits are used.

In forming an earthenware pipe-conduit great care must be taken to make the trench water-tight, and then to lay and joint the pipes so as to secure that the conduit shall be sound and tight through its whole length, to prevent leakage into the subsoil, and to obviate the risk of impure water from the subsoil entering the pipe.

In forming a conduit the pipes should be laid in straight lines, from point to point. There should be means of inspection and ventilation in each quarter mile at the least, and of washing out at all convenient points.

Valley lines may be crossed by means of cast-iron syphon pipes; that is, a pipe may be laid across a valley to conduct the water under pressure.

All valley, or syphon, lines should have double the fall in their length of the ordinary conduit.

There should be means provided to wash out and cleanse such syphon-pipe or pipes at the lowest point.

Cast-iron pipes should be coated inside and out with black varnish.

Turned and bored joints are cheapest, but joints made with lead are probably the safest.

Wrought-iron pipes with screw joints may be used up to $1\frac{1}{2}$ inch diameter.

Cast or wrought-iron, not lead, should be used for elevated tanks and cisterns.

Tanks to store rain-water may be of brick, of masonry, or of concrete. They should either be arched over, or be roofed, so as to protect the water from the direct action of the sun and from fouling.

The ground excavated for the formation of a main service tank (Plate 15) should be made perfectly water-tight. The bottom may be covered with concrete or with clay-puddle and the side-walls be backed or lined with concrete or with clay-puddle. The thickness of the puddle should not be less than 12 inches.

If the site selected for a main service tank is sand, gravel, or open jointed rock, great care must be taken to give the puddle a full and even bearing over the whole surface

* Wrought-iron service-pipes for gas are laid in a wooden trough V shaped, which is filled with asphalte or with Portland lime concrete placed around and over the pipe so as to protect it from the subsoil. Some of the London gas companies protect wrought-iron pipes in this manner.

area; open joints in rock must be cleaned out and then be filled up with concrete. In gravel large stones must be removed and the entire surface brought to a level, smooth, and even plain. Clay-puddle will only resist the pressure of water when it rests solidly on an even water-tight bed, so as to prevent the water forcing holes through it, which will be the case if there is a rough uneven surface and open spaces, for however small the spaces beneath may be, water, when under sufficient pressure, will penetrate them.

Main service tanks require to have an inlet-pipe, an outlet or supply-pipe, a wash-out or cleansing and an overflow-pipe. These latter, the cleansing and overflow, may be joined.

The main tank or tanks should have valve-wells so arranged as to enable the system of supply to be carried on independently of the main tank.

On Plate (No. 15) attached hereto is shown a plan and section of a main service underground storage tank with valve-wells.

By this arrangement the supply of water will flow direct to the inlet-well, and may be passed on through this well to the main tank; the supply may be obtained from the outlet well by opening the valve in the main tank and the valve in the supply well. By closing the valves communicating with the main tank in both wells, and opening the valve on the end of the connecting pipe in the inlet-well and the valve on the supply-pipe in the outlet-well, the supply of water may go on independently of the main tank. The overflow must be formed at the inlet-well to be connected with the wash-out. There must be manhole openings in the covering arches, and end windows in each bay, as shown on Plate No. 15. This is merely a sketch to show the general arrangements.

Elevated tanks for immediate or daily supply of water should be of cast-iron or of wrought-iron. Cast-iron requires more practical skill in construction. Plan 15.

In arranging cast-iron tanks of large dimensions care must be taken to support the bottom and stay the sides. The tie-rods should pass through the tank-plates and be secured to outside washers and not to internal angle-iron.

Cast-iron or wrought-iron main supply tanks (Plan 15) should be arranged so that the supply of water may be carried on in a corner compartment, as shown in the sketch of a cast-iron tank, with a separate supply cistern, to allow of the main tank being repaired, cleaned, and occasionally painted or varnished.

Junctions of bolts and tie-rods may give way if not repaired in time. Cleaning and painting should therefore be regularly done once a year.

Wrought-iron tie-rods must not have a strain exceeding six tons for each square inch of cross sectional area of the best iron rods.

Iron house service-tanks should not be exposed to the direct action of the sun, but should be clothed. An enclosure of boards with felt beneath will form a good protection. Water, especially for drinking, must be kept cool.

The sketch No. 15 is not complicated by showing any details of tank-plates or tie-rods, but is intended only to show the proposed mode of arranging a small inner tank, within which all the operations of supply may be carried on independently of the larger tank. This will be found to be of the utmost importance in use. The small tank will be connected with the larger tank by means of a pipe having a valve on it.

In arranging a main-pipe from pumps, the pumping-main-pipes should have sectional capacity sufficient to allow of the velocity in such main-pipe not exceeding two feet per second.

Where a river flows through a valley over porous substrata, sinking a well or wells in the strata within the influence of the river filtration is a cheap and ready method of obtaining river-water naturally filtered. Wells so situated must, however, be carried above the level of extreme floods, and the filtering must be effective.

If a single well on a river bank does not produce sufficient water, or if the subsoil is clay impervious to water, then trenches may be excavated parallel to the river or stream, in which trenches perforated earthenware pipes may be laid, leading to a well or wells. The trenches above such pipes should be filled in with fine assorted gravel, charcoal, and sand, so as to form a filtering medium within reach of the dry weather flow of such stream or river. These trenches should not be less than six feet deep to the top of the pipes.

Any overflow or waste-water pipe from a service reservoir or tank should deliver the water at an open end into a channel, sewer, or drain, so as to prevent gases rising back through such overflow or waste-water pipe to the water in the reservoir or tank, a result very apt to follow if the pipe is directly connected with the sewer or drain.

Water readily absorbs foul gases, and may become poisonous by such means. The possibility of such contamination taking place must therefore be prevented.

Waterworks conduits should be laid at such depth and be so covered with earth as to prevent the water becoming heated unduly by the rays of the sun, or being injuriously affected by frost in winter. This depth may be considered as not less than 3 feet.

Brick and masonry tanks, if arched, may be covered in with sand or fine earth to the depth of 18 inches, which will preserve the water cool.

All covered reservoirs and tanks should be ventilated.

All supply-pipes should be arranged in such manner as to allow of easy inspection and subsequent repairs. Stop-taps should be placed betwixt the main and the building in all cases, so as to allow of isolation of any line of service-pipe for repairs.

All house service-tanks and service-pipes should be fixed in such manner that the best rooms shall not be flooded in case of leakage or overflow.

Ready means of access to all tanks and cisterns should be provided to allow of inspection, cleansing, or repairs. Where gas is in use a jet, or ring of jets, may be so placed that during severe frosts the pipes and tanks shall be preserved from freezing.

Up-bends should not be formed on lines of main-pipes or on service-pipes. If up-bends are inevitable, air-valves should be provided to let out the air at such bends.

Bends should not be formed at right angles on pipes, but the pipe should be brought round in a curve.

All mortar used in waterworks should be capable of setting under water.

Portland or Roman cement may be used.

Deep well-sinking or deep boring necessarily involves special knowledge and appropriate and special tools. A description of such work and such tools is not needed by a practical well-sinker, and would not be of use to anyone else. But for certain information on this head, *see* Appendix C., page 25.

A public supply of water should not (if practicable) be less in volume than 15 gallons daily per head of the population. This, in towns below 20,000 population, will include water for public purposes and for trade requirements. For villages it may not be possible to obtain more than from five to ten gallons per head. High-pressure and constant-service should be secured wherever practicable.

Water at and below six degrees of hardness is considered "soft water:" above this range water is termed "hard."

Hardness in water implies one grain of bi-carbonate or sulphate of lime in each gallon of water.

Each degree of hardness destroys $2\frac{1}{2}$ ozs. of soap in each 100 gallons of water used for washing. Soft water is, commercially, of more value than hard water, in proportion to the worth of 5 ozs. of soap to each 200 gallons for each degree of hardness.

Where water is drawn from a river, and is occasionally turbid, there should be sufficient reservoir capacity to receive and store not less than ten (10) days supply to allow of subsidence before filtration.

Sand-filters should not be forced to filter at a greater rate than about 50 gallons for each superficial foot of sand surface, in each 24 hours.

Sand-filters will require surface cleansing, probably on an average not less than twelve times in each year. During hot summer weather surface cleansing may be required at intervals of a week. It will be of the utmost importance to filter through clean materials at all times.

Impounding Reservoirs.—Care is required in selecting a site for an impounding reservoir to ascertain if the area to be covered with water will be water-tight, or can at a moderate cost be made so.

Areas of millstone-grit, mountain-limestone, the coal-measures, the oolites, and other strata liable to be fissured, or have open-jointed rock, may be treacherous and difficult to make water-tight, and if material to form part of the embankment is excavated from the inner area, so as further to open the strata, the site may be ruined.

An artificial embankment should have a water-tight and sound base; the depth of the puddle-trench must depend upon the nature of the strata.

The outer portion of the embankment must be effectively drained, and if there are springs of water in the puddle-trench (as there usually are) these must be collected and brought away. The entire bottom area of a puddle-trench had better be filled with rich Portland lime concrete, and all the drains beneath the bank be protected with similar concrete.

A top-water conduit may be made to convey the stream during the construction of the works, or there may be a flood-water culvert through the solid ground on one side, to safely convey the water during the construction of the embankment.

No form of culvert or other works for drawing off water should be constructed within or beneath or through the deepest made portion of the bank, but the outlet-tunnel, valve-chamber, and works connected with drawing off the water of the completed reservoir must be in the solid ground, on one side of the valley ; the outlet-tunnel and valve-well may be of cast-iron, of brick, or of concrete, and may have its invert 10 or 15, or even up to 20 feet above the bottom of the reservoir at the inner toe of the bank. This tunnel may be level. At the centre of the bank the valve-chamber should be formed and should be divided by a cast-iron vertical mid-feather, in which cast-iron division the valves must be placed, one above the other, communicating with a vertical pipe in the outer half of the valve-chamber.

A syphon-pipe may be laid along the invert of the outlet-tunnel to draw the portion of water below the invert at any time this is required.

The outlet-tunnel must communicate with the water in the reservoir and with the stream outside; that is, there must be culverts at each end of the outlet-tunnel for these purposes.

An overflow, or bye-wash, must always be formed in the solid ground, and must be in steps, so as to limit any fall to about three feet.

It will be a safe rule to provide three feet of bye-wash for each hundred acres of gathering-ground.

Impounding-reservoirs, if constructed in accordance with these suggestions, will have neither pipes nor valves buried beyond repairs or renewals. The artificial bank will be undisturbed by works, the head of water on the outlet-valves will be reduced, and at the tier of valves in the valve-well no valve need be worked under a greater head than some 10 or 15 feet. Formerly it was common to lay cast-iron pipes, or to form culverts of brick or stone beneath reservoir banks at their deepest part, and to wall in the outlet-valves so as to have, in some cases, 100 feet head of pressure: culverts, cast-iron pipes, and valves, being buried and fixed so as to be impossible to repair, without for the time destroying the embankments.

APPENDICES.

APPENDIX A.

PUBLIC HEALTH ACT, 1875.

CONTRACTS AND SPECIFICATIONS.

The Act provides as under:—

Sect. 173. Any Local Authority may enter into any Contracts necessary for carrying this Act into execution. **Power of Local Authorities to contract.**

Sect. 174. With respect to Contracts made by an Urban Authority under this Act, the following regulations shall be observed; namely, **Provisions as to Contracts by Urban Authority.**

(1.) Every Contract made by an Urban Authority whereof the value or amount exceeds 50*l.*, shall be in writing and sealed with the common seal of such authority.

(2.) Every such Contract shall specify the work, materials, matters, or things to be furnished, had, or done, the price to be paid, and the time or times within which the Contract is to be performed, and shall specify some pecuniary penalty to be paid in case the terms of the Contract are not duly performed.

(3.) Before contracting for the execution of any works under the provisions of this Act, an Urban Authority shall obtain from their surveyor an estimate in writing as well of the probable expense of executing the work in a substantial manner as of the annual expense of repairing the same; also a report as to the most advantageous mode of contracting, that is to say, whether by contracting only for the execution of the work, or for executing and also maintaining the same in repair during a term of years or otherwise.

(4.) Before any Contract of the value or amount of 100*l.* or upwards is entered into by an Urban Authority, ten days public notice at the least shall be given, expressing the nature and purpose thereof, and inviting tenders for the execution of the same; and such authority shall require and take sufficient security for the due performance of the same.

(5.) Every Contract entered into by an Urban Authority in conformity with the provisions of this section, and duly executed by the other parties thereto, shall be binding on the authority by whom the same is executed and their successors, and on all other parties thereto, and their executors, administrators, successors, or assigns, to all intents and purposes: Provided that an Urban Authority may compound with any Contractor or other person in respect of any penalty incurred by reason of the non-performance of any Contract entered into as aforesaid, whether such penalty is mentioned in any such Contract or in any bond or otherwise, for such sums of money or other recompense as to such authority may seem proper.*

Contracts for sewering may provide as under:—

For excavating, trenching, laying in sewers or drains, and making the ground good.

For providing all materials, as bricks, stone, earthenware-pipes and iron-castings. For providing all necessary implements for the due execution of the works, and also providing timber necessary for securely shoring excavations and buildings during the progress of the works.

Contracts may be let as a whole, the Contractor finding implements, materials, and labour, and completing the works as specified; or Contracts may be let for labour only, the Local Authority providing, by separate Contracts, all materials, such as bricks, earthenware-pipes for sewers and drains, and also iron-work, such as gulley-grates and main-sewer ventilating-grates.

N.B.—The Local Authority should provide any land required, as also arrange for way-leave for sewers and drains.

Main sewer Contracts may be subdivided into several Contracts. Where the entire cost of the materials and works will not exceed 1,000*l.* it may be advisable to provide for one Contract; for more extensive works there may be several Contracts.

Main sewering Contracts should not be let in one lump sum, but by schedule of prices. Petty measurements of the work done to be made monthly, and 75 per cent. of the Contract price paid on account. A final measurement to be made on the completion of the works, which, with a copy of the plans and sections, and a book of reference, should be delivered to the Board.

Alterations of any sort, either in materials, labour, depth of sewer-trenching, timbering the trenches in dangerous ground, or timbering adjoining buildings, to be done under special order from the engineer for the time being, or his clerk of works, who shall at once report the incident to the local authority through their clerk. These orders to be retained, and with certificates for payments on account, be signed by the surveyor or engineer and must be embodied in the final statement.

During the progress of any works a correct record should be made and kept of every incident liable to be of interest, or in any way likely to affect a settlement of the Contract; as, the nature of

* Before a Surveyor or Sanitary Engineer is employed the Local Authority should ascertain the rate of charge proposed to be made, and, where practicable, an agreement should be entered into as to the amount to be paid for the work to be done.

the ground when opened out, and especially as to the occurrence of water or quicksand in trenches necessitating extra precautions, such as permanently timbering a trench or filling above a sewer with concrete, or substituting cast-iron pipes for earthenware pipes, &c. Correct measurements being made in each case of the timber or of the concrete.

Letting Contracts for main sewering at a lump sum cannot be considered satisfactory either for the engineer, the contractor, or the Local Authority.

A Contract will usually provide—

For filling in sewer and drain trenches, ramming the earth, making the ground good, and replacing pavements or macadam, as the case may be.

For fencing, watching, and lighting any open sewer-trenches during the progress of the works. In some cases it may be advisable for the Local Board to appoint any watchman required for special occasions, the contractor paying the wages.

For the maintenance of road and street surfaces during some specified period after the completion of the works.

For the removal of all surplus material as speedily as possible on the completion of the works.

A Contract for bricks should be for sound bricks as per Specification; broken or defective bricks should be rejected as not in accord with the Specification, and should not be paid for.

Earthenware sewer and drain-pipes should be delivered sound and free from defects. Broken or blemished pipes should be rejected and be removed at the cost of the Contractor.

Portland lime should be delivered fresh, and in strength should be equal to the specified standard. Any lime or cement found on trial to be defective must (after due notice) be at once removed at the cost of the Contractor.

NOTE.—All lime used in main sewerage works should be of an hydraulic character, and should only be used in a fresh state, capable of setting under water.

Specifications should be full but short. Each class of work being described accurately.

The bill of quantities should set forth the probable amount of the work under appropriate heads, as "1,000 lineal yards of main sewer, 12 inches diameter, laid at an average depth of eight feet. "Price per lineal yard."

The schedule of prices should set forth in proper form each class of work—

Materials separately.

Workmanship separately.

NOTE.—Brickwork to include cement, or mortar, and labour.

Earthenware pipe-laying to include the material for joints.

APPENDIX B.

INSTRUCTIONS as to applications for PROVISIONAL ORDERS to put in force the COMPULSORY POWERS of the LANDS CLAUSES CONSOLIDATION ACTS.

1. The application must be made by a petition under the seal of the Sanitary Authority, containing the particulars required by section 176 (3) of the Public Health Act, 1875.

2. The petition must be presented not later than the 1st January, if the advertisements of the proposal were published in September or October, and not later than the 1st February, if they were published in November.

3. The petition should be accompanied by a plan of the proposed undertaking, by a book of reference in duplicate, and by a statutory declaration showing that the requirements of section 176 of the Public Health Act, with respect to advertisements and notices, have been duly complied with. The declaration must be properly stamped, and copies of the newspapers containing the advertisements, and also of the form of notice, should be annexed to it as exhibits. It should specify the manner in which the notices were served upon the owners, lessees, and occupiers, and, so far as relates to these notices, it should be made by the persons who served them. With regard to the mode of service, see section 267 of the Public Health Act, 1875. The plan should be coloured so as to distinguish the land proposed to be actually purchased, and the several properties should be numbered so as to correspond with the book of reference.

4. The Standing Orders of both Houses of Parliament require that, *at the same time* as the plan of the undertaking and the book of reference are deposited with the Board, duplicates thereof shall be deposited with the clerk of the Parliaments and at the Private Bill Office, unless the deposit with the Board is made after the prorogation of Parliament and before the 30th November, in which case the deposit with the clerk of the Parliaments, and at the Private Bill Office, must be made on the day last mentioned.

In order that compliance with these requirements may be proved before the examiners of Standing Orders, the Board should be furnished with an *affidavit*, duly stamped and sworn before a justice of the peace or a commissioner for taking affidavits by the person by whom the deposits have been made.

II.—APPLICATIONS for PROVISIONAL ORDERS to alter the AREAS of SANITARY DISTRICTS.

1. The Application should be made by a resolution of the Sanitary Authority, a copy of which should be forwarded to the Board.

2. The application must be made not later than the 1st January.

3. The application should be accompanied by (*a*) a statement giving the names of the Sanitary Authorities whose districts are affected by the proposal, and the grounds upon which the application is made, (*b*) a map showing the present and proposed boundaries of the districts affected, and (*c*) a description, without reference to a map, of the boundaries of the part proposed to be added or detached, or formed into a new district, as the case may be. Where part of a rural sanitary district is affected, the name of the contributory place should be given.

III.—APPLICATIONS for PROVISIONAL ORDERS to repeal, alter, or amend LOCAL ACTS.

1. The application should be made by a resolution of the Sanitary Authority, asking the Board in general terms to repeal, alter, or amend the Local Act wholly or partially, as the case may require. A copy of the resolution should be forwarded to the Board.
2. The application must be made not later than the 1st January.
3. The application should be accompanied by a copy of the Local Act, and by a statement showing the particular sections which it is proposed should be repealed, altered, or amended, and the precise alteration desired. The statement should also show the grounds upon which the application is made.
4. Where the effect of the proposed repeal or alteration of the Local Act will be to extend or diminish the area of a sanitary district, the particulars referred to in Instruction II., 3, should also be furnished.

N.B.—It is particularly requested that all petitions, statutory declarations, and other such documents may be written on foolscap paper of the usual size.

APPENDIX C.

Local authorities are frequently at a loss to know what to do with respect to constructing wells, or boring and sinking to obtain water. The following lists of prices may be usefully consulted, but of course, each locality will require to be specially examined preliminary to preparing an estimate for water-works.

SCHEDULES of Prices for Sinking Wells, and for Boring, prepared and submitted by a practical well-sinker. For well-sinking in Clay, Chalk, or Red Sandstone, and also for boring in the same formations.

The prices are given up to 100 feet for red sandstone, very rarely we sink lower, and clay and chalk would average about 200 feet.

In quoting these prices, I would observe that they will vary according to circumstances, in some places higher, and in others lower. It entirely depends upon position, but they may be taken as average prices upon the whole.

With reference to obtaining a supply of water from lower formations it is practicable to dispense with well-sinking, and merely make a bore-hole in which is inserted a long barrel pump, easily repaired from the surface. These pumps can be worked at any depth.

At Champion's Vinegar Works, City Road, London, there is a 12″ bore-hole to and some 150 feet into the chalk, a 7″ pump is fixed in the 12″ pipe, and this pump is driven by a 6-horse power horizontal engine, which works effectively, and throws about 100 gallons per minute; and at Sevenoaks, a 4″ bore-hole, 350 feet deep, in which is fixed a 2½″ pump, having a 2 feet stroke, the pump being worked by a 3-horse power vertical steam engine. This pump supplies the establishment and farm yard, and requires scarcely any attention.

SCHEDULE of Prices for Sinking Wells in Red Sandstone.—Pumping extra.

4	feet	diameter	to depth of	100	feet,	20*s.* per foot run.
5	„	„	„	100	„	30*s.* „
6	„	„	„	100	„	40*s.* „
7	„	„	„	100	„	60*s.* „

SCHEDULE of Prices for Sinking Wells in Chalk.—Brickwork and Pumping extra.

4	feet	diameter	to depth of	200	feet,	18*s.* per foot run.
5	„	„	„	200	„	24*s.* 6*d.* „
6	„	„	„	200	„	27*s.* 6*d.* „
7	„	„	„	200	„	35*s.* „

SCHEDULE of Prices for Sinking Wells in Clay, lined with 9″ brickwork in Portland cement.—Wooden curves, cylinders, and pumping extra.

4 feet diameter to depth of 200 feet, 50*s.* per foot run.
5 „ „ „ 200 „ 65*s.* „
6 „ „ „ 200 „ 85*s.* „
7 „ „ „ 200 „ 105*s.* „

SCHEDULE of Prices for making Bore-holes in Red Sandstone.

Diameter.	——	First 100 Feet.	Second 100 Feet.	Third 100 Feet.	Fourth 100 Feet.
Inches.		£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
3	@ per foot run - -	0 5 6	0 7 6	0 11 6	0 14 6
4	„ - -	0 5 6	0 7 6	0 11 6	0 14 6
5	„ - -	0 7 6	0 10 6	0 13 6	1 0 6
6	„ - -	0 8 6	0 11 6	0 14 6	1 0 6
7	„ - -	0 9 6	0 12 6	0 16 6	1 2 6
8	„ - -	0 9 6	0 12 6	0 16 6	1 2 6
9	„ - -	0 12 6	0 15 6	1 0 6	1 5 6
10	„ - -	0 13 6	0 16 6	1 1 6	1 6 6
11	„ - -	0 17 6	1 1 6	1 5 6	1 10 6
12	„ - -	0 17 6	1 1 6	1 5 6	1 10 6

SCHEDULE of Prices for making Bore-holes in Chalk.

Diameter.	——	First 100 Feet.	Second 100 Feet.	Third 100 Feet.	Fourth 100 Feet.
Inches.		£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
3	@ per foot run - -	0 4 0	0 7 0	0 11 0	0 15 0
4	„ - -	0 4 0	0 7 0	0 11 0	0 15 0
5	„ - -	0 6 0	0 10 0	0 15 0	1 0 0
6	„ - -	0 6 0	0 10 0	0 15 0	1 0 0
7	„ - -	0 8 0	0 12 0	0 17 0	1 0 0
8	„ - -	0 9 6	0 13 6	0 18 6	1 1 6
9	„ - -	0 9 6	0 13 6	0 18 6	1 1 6
10	„ - -	0 12 0	0 16 0	1 0 0	1 5 0
11	„ - -	0 14 0	0 18 0	1 3 0	1 8 0
12	„ - -	0 16 0	1 0 0	1 5 0	1 10 0

SCHEDULE of Prices for making Bore-holes in Sand and Clay.

Diameter.	——	First 100 Feet.	Second 100 Feet.	Third 100 Feet.	Fourth 100 Feet.
Inches.		£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
3	@ per foot run - -	0 4 0	0 9 0	0 14 0	0 19 0
4	„ - -	0 6 0	0 10 0	0 15 0	1 0 0
5	„ - -	0 7 6	0 11 6	0 16 6	1 1 6
6	„ - -	0 7 6	0 11 6	0 16 6	1 1 6
7	„ - -	0 3 6	0 12 6	0 17 6	1 2 6
8	„ - -	0 10 6	0 14 6	0 19 6	1 4 6
9	„ - -	0 11 6	0 16 6	1 0 6	1 5 6
10	„ - -	0 14 6	0 19 6	1 4 6	1 10 6
11	„ - -	0 14 6	0 19 6	1 4 6	1 10 6
12	„ - -	0 16 6	1 0 6	1 6 6	1 14 6

SCHEDULE of Prices for Cast-iron Bore Pipes fixed in Bore-holes agreeable to Standard List.

Diameter.	——	——	EXTRA for Steel Shoe on Bottom Pipe.
Inches.		£ s. d.	£ s. d.
3	@ per foot run - -	0 4 0	0 12 0
4	„ - -	0 5 6	0 16 0
5	„ - -	0 6 6	1 0 0
6	„ - -	0 7 8	1 5 0
7	„ - -	0 8 6	1 10 0
8	„ - -	0 10 6	2 0 0
9	„ - -	0 11 6	2 15 0
10	„ - -	0 13 0	3 10 0
11	„ - -	0 15 0	4 6 0
12	„ - -	0 18 6	5 5 0

These prices would also apply to wrought-iron pipes.

ROUGH ESTIMATE of Cost of Well-sinking in N. Hants, through Clay, Chalk, and Gravel.

Diameter of Well.	Depth not exceeding	Price per foot of depth.	Total cost.
		£ s. d.	£ s. d.
4 feet - -	50 feet - - -	0 3 0	7 10 0
„ - -	100 „ - - -	0 5 0	25 0 0
„ - -	150 „ - - -	0 7 0	52 10 0
5 feet - -	50 feet - - -	0 4 6	11 5 0
„ - -	100 „ - - -	0 6 0	30 0 0
„ - -	150 „ - - -	0 9 0	67 10 0
„ - -	200 „ - - -	0 11 0	120 0 0
6 feet - -	100 feet - - -	0 9 0	45 0 0
„ - -	150 „ - - -	0 12 0	90 0 0
„ - -	200 „ - - -	0 15 0	150 0 0
„ - -	250 „ - - -	0 18 0	225 0 0
„ - -	300 „ - - -	1 1 0	315 0 0
7 feet - -	100 feet - - -	0 12 0	60 0 0
„ - -	150 „ - - -	0 15 0	112 10 0
„ - -	200 „ - - -	0 18 0	180 0 0
„ - -	250 „ - - -	1 1 0	262 10 0
„ - -	300 „ - - -	1 6 0	390 0 0
„ - -	350 „ - - -	1 12 0	560 0 0

Entirely exclusive of all brickwork or fittings.

APPENDIX D. - - - - - -

TABLE showing the PRIME COST and EFFICIENCY of various MACHINES for raising Water. - -

See Appendix No. 4 to the Report of the Select Committee of the House

The tabulated form of the relative cost of various kinds of power to raise water for village supplies can only be regarded as approximate in prices. so far as they go. The list of makers is given, and each will, on

System No.	NAME OF FIRM.	CATALOGUE. No.	CATALOGUE. Page.	SOURCE OF POWER.	DESCRIPTION OF PUMP.	Depth.	Height.	TOTAL.	
1	Gwynne & Co., Essex-street, Strand, W.C.	32	78 and 79	Water - - -	Hydraulic ram -	10 ft.	40 ft.	50 ft.	1
2	Gwynne & Co., Essex-street, Strand, W.C.	32	78 and 79	Water - - -	Hydraulic ram -	0 surface only.	50 ft.	50 ft.	2
3	S. Owens & Co., Whitefriars-street, Fleet-street, E.C.	No. 0, July 1872.	50 to 55	Water - - -	Hydraulic ram -	0 surface only.	50 ft.	50 ft.	3
4	John Warner & Sons, Crescent Foundry, Cripplegate.	No. 0, A.D. 1872.	6	Water (overshot wheel) -	Treble pumps -	20 ft.	50 ft.	70 ft.	4
5	Gwynne & Co., Essex-street, Strand, W.C.	No. 32. A.D. 1872.	97 75	Water (turbine) - -	Treble pumps - -	20 ft.	50 ft.	70 ft.	5
6	John Warner & Sons, Crescent Foundry, Cripplegate.	A.D. 1875.	7	Wind and Horse.—Annular sail mill and horse-gear.	Treble pumps - -	80 ft.	50 ft.	130 ft.	6
7	John Warner & Sons, Crescent Foundry, Cripplegate.	A.D. 1875.	8	Wind and Steam.—Annular sail mill and combined vertical boiler and 2 H.P. engine.	Treble pumps - -	80 ft.	50 ft.	130 ft.	7
8	Hayward, Tyler, & Co., 84, Upper Whitecross - street, London, E.C.	March A.D. 1874.	132 to 130	Horse or Cattle.—Horse gear (No. 410) for two horses.	Treble pumps - -	100 ft.	30 ft.	130 ft.	8
9	Hayward, Tyler, & Co., 84, Upper Whitecross - street, E.C.	March A.D. 1874.	132 to 146	Manual labour.—H., T., & Co., well engine.	Double pumps -	28 ft. maximum lift.	30 ft.	58 ft.	9
10	Hayward, Tyler, & Co., London.	1878.	16 and 17	Hot Air.—Rider's patent hot-air engine.	Single barrel 3″ pump	40 ft.	30 ft.	70 ft.	10
11	Hayward, Tyler, & Co., London.	1878.	4 and 5 12	Hot Air.—Rider's patent hot-air engine.	Single barrel lift and force pump.	28 ft. maximum lift.	30 ft.	58 ft.	11
12	Hayward, Tyler, & Co., London.	March A.D. 1874.	18 and 19 2nd part.	Steam.—Patent "Universal" direct-acting pump.	Single barrel double-acting pump.	28 ft. maximum lift.	30 ft.	58 ft.	12
13	Hayward, Tyler, & Co., London.	March A.D. 1874.	64 2nd part of catalogue	Steam.—H., T., & Co.'s vertical engine and boiler with gearing.	Treble barrel "Deep Well" pumps.	100 ft.	30 ft.	130 ft.	13
14	Crossley Brothers, Manchester.	March 1877.	6	Gas.—Otto's Gas engine -	Treble pump, 2½ inch barrels.	50 ft.	30 ft.	80 ft.	14

NOTE.—There are other makers whose names may be found in the London Directory. The names selected manufacture and supply the and would be increased with any rise in

APPENDIX D.

TABLE showing PRIME COST and EFFICIENCY of various MACHINES for raising Water.

of Commons on the Public Health Act (1875) *Amendment Bill, No.* 134, 1878.

Each place will have special peculiarities which may add to the ultimate cost of works; the several estimates, may, however, be taken as reliable special application, furnish estimates when all the details have been given.

	Gallons per hour.	DETAILS OF COST.	£ s. d.	TOTAL COST (APPROXIMATE).	£ s. d.	REMARKS.
1	250 gallons night and day.	Gwynne & Co.'s improved double-acting hydraulic ram, No. 5 size, 3″ delivery pipe. Fixing, &c. - - -	70 0 0 10 0 0	Price of No. 5 ram fixed.	80 0 0	This patent ram, deriving its power from a stream or pond, will throw pure water drawn from a well or spring, and might be used in mining districts.
2	250 gallons night and day.	Single-acting hydraulic ram, No. 5 size. Pipes and fixing - -	47 0 0 8 0 0	Ram fixed - -	55 0 0	Hydraulic rams when fixed require no attention and no repairs until the end of two or three years, when new valves, at a cost of 30*s.*, may be necessary.
3	250 gallons night and day.	Single-acting hydraulic ram, No. 5. Fixing - - -	55 0 0 3 0 0	Ram fixed complete.	58 0 0	The quantity of water thrown by hydraulic rams varies inversely as the height to which it is thrown. The less the height the greater the quantity.
4	250 gallons night and day.	Water wheel, three-throw crank and treble two-inch pumps. Race, fixing, &c. - -	60 0 0 30 0 0	Wheel and pumps fixed complete for drawing from well not exceeding 20 feet deep.	90 0 0	Water wheels may use foul water, and pump from a well of any depth, and throw to any required height, at an additional first cost.
5	250 gallons night and day.	1 HP. turbine (for a 10 foot fall of water). Treble pump 2¼″ barrels Well gear, fixing, &c. -	33 0 0 20 10 0 30 0 0	Turbine and pumps fixed complete for drawing 20 feet.	83 10 0	When the water supplying the turbine is pure, or if pumping from a well the depth be not exceeding 10 feet, "a centrifugal pump," at about the same price as the "plunger pumps," will be more effective.
6	900 gallons varying.	2 HP. wind engine - Horse gear - - - Clutches, shafting, &c. Set of treble pumps, No. 122.	85 0 0 36 0 0 19 0 0 55 0 0	Price, including 20*l.* for fixing pump, rods, stages, &c.	215 0 0	At a slight additional cost this set of apparatus would raise the water from a well of any depth, and would deliver to a height of 200 feet if necessary. Messrs. W. could no doubt make a smaller size.
7	900 gallons varying.	2 HP. wind engine - 2 HP. vert. boiler and steam-engine. Clutches, shafting, &c. Set of treble pumps - Fixing, &c. - - -	85 0 0 80 0 0 15 0 0 55 0 0 20 0 0	Total cost fixed -	255 0 0	Four days a week of 10 hours each would raise 36,000 gallons. This combination, although more expensive than the last, is a good one, and could be made to draw from a much deeper well, and force to a greater height at slight additional cost.
8	1,000 gallons six hours.	Two horse gear with treble crank pumps, 3-inch diameter, 10-inch stroke, air vessel, rods, &c.	72 0 0	Price, including 10*l.* for fixing.	82 0 0	Six hours daily working would raise 6,000 gallons.
9	1,000 gallons six hours.	Well-engine, with double pumps, 3½ inch. Suction and delivery pipe and foot valve.	34 0 0 6 0 0	Price, including 5*l.* for fixing.	45 0 0	To raise 6,000 gallons requires the labour of two men for six hours.
10	1,000 gallons six hours.	No. 2 size, Rider's patent hot-air pumping engine 3-inch pumps, Pipes, valves, and fixing	56 0 0 42 0 0	Total cost - -	98 0 0	It is claimed for these engines that 5*s.* a week will pay for all coal and oil, and that they only require to have the fire replenished once in every hour.
11	600 gallons 10 hours.	Rider's patent hot-air pumping engine, No. 1 size. Pipes, valves, and fixing	42 0 0 18 0 0	Total cost - -	60 0 0	If worked for 10 hours, will pump 6,000 gallons to height stated. In system, No. 7 (*ante*), this engine could be substituted for steam-engine.
12	2,000 gallons per hour.	Engine, boiler, and pumps complete on one bed-plate, 30 feet suction pipe and foot valve.	100 0 0	Total price, fixed -	110 0 0	If the tank were sufficiently large, this apparatus would be worked in the cheapest way by pumping two days a week only; in 20 hours, 40,000 gallons.
13	1,000 gallons per hour.	1½ HP. engine, boiler, gearing, well rods, cast-iron stages, &c. and pumps.	125 0 0	Price, including 15*l.* for fixing complete.	140 0 0	This apparatus could be worked every other day for 10 hours; at a slight additional cost, for well rods and staging, this apparatus could draw from any reasonable depth.
14	1,000 gallons per hour.	Gas engine - - - Pumps - - - Well gear and fixing -	76 10 0 20 10 0 30 0 0	Total cost	127 0 0	Where gas is supplied at 4*s.* per 1,000 feet, the cost of working will be about a halfpenny per hour.

articles tabulated, and also make and supply other forms of machines. The details, as regards prices, are only true under certain conditions, the costs of material and labour,

APPENDIX E.

SPECIMEN REGULATIONS.

The following Regulations as to House Fittings for Water Supply in the Metropolis, settled by the Board of Trade, will be found useful for other Towns.

REGULATIONS MADE UNDER THE METROPOLIS WATER ACT, 1871.

Place of communication-pipe.

1. No "communication-pipe" for the conveyance of water from the water-works of the Company into any premises shall hereafter be laid until after the point or place at which such "communication-pipe" is proposed to be brought into such premises shall have had the approval of the Company.

Weight of lead pipes.

2. No lead pipe shall hereafter be laid or fixed in or about any premises for the conveyance of or in connexion with the water supplied by the Company (except when and as otherwise authorised by these regulations, or by the Company), unless the same shall be of equal thickness throughout, and of at least the weight following, that is to say :—

Internal Diameter of Pipe in Inches.	Weight of Pipe in lbs. per lineal Yard.
⅜-inch diameter.	5 lbs. per lineal yard.
½ " "	6 " "
⅝ " "	7½ " "
¾ " "	9 " "
1 " "	12 " "
1¼ " "	16 " "

Interior pipes.

3. Every pipe hereafter laid or fixed in the interior of any dwelling-house for the conveyance of, or in connexion with, the water of the Company, must, unless with the consent of the Company, if in contact with the ground, be of lead, but may otherwise be of lead, copper, or wrought iron, at the option of the consumer.

Not more than one communication-pipe to each house.

4. No house shall, unless with the permission of the Company in writing, be hereafter fitted with more than one "communication-pipe."

Every house, with certain exceptions, to have its own communication-pipe.

5. Every house supplied with water by the Company (except in cases of stand pipes) shall have its own separate "communication-pipe." Provided that, as far as is consistent with the special Acts of the Company, in the case of a group or block of houses, the water-rates of which are paid by one owner, the said owner may, at his option, have one sufficient "communication-pipe" for such group or block.

No house to have connexion with fittings of adjoining house.

6. No house supplied with water by the Company shall have any connexion with the pipes or other fittings of any other premises, except in the case of groups or blocks of houses, referred to in the preceding Regulation.

Connexion to be by ferrule or stop-cock.

7. The connexion of every "communication-pipe" with any pipe of the Company shall hereafter be made by means of a sound and suitable brass screwed ferrule or stop-cock with union, and such ferrule or stop-cock shall be so made as to have a clear area of waterway equal to that of a half-inch pipe. The connexion of every "communication-pipe" with the pipes of the Company shall be made by the Company's workmen, and the Company shall be paid in advance the reasonable costs and charges of and incident to the making of such connexion.

Material and joints of external pipes.

8. Every "communication-pipe" and every pipe external to the house and through the external walls thereof, hereafter respectively laid or fixed in con-

nexion with the water of the Company shall be of lead, and every joint thereof shall be of the kind called a "plumbing" or "wiped" joint.

No pipe to be laid through drains, &c.

9. No pipe shall be used for the conveyance of, or in connexion with, water supplied by the Company, which is laid or fixed through, in, or into any drain, ashpit, sink, or manure-hole, or through, in, or into any place where the water conveyed through such pipe may be liable to become fouled, except where such drain, ashpit, sink, or manure-hole, or other such place, shall be in the unavoidable course of such pipe, and then in every such case such pipe shall be passed through an exterior cast-iron pipe or jacket of sufficient length and strength, and of such construction as to afford due protection to the water-pipe.

Depth of pipes under ground.

10. Every pipe hereafter laid for the conveyance of, or in connexion with, water supplied by the Company, shall, when laid in open ground, be laid at least two feet six inches below the surface, and shall in every exposed situation be properly protected against the effects of frost.

No connexion with rain water receptacle.

11. No pipe for the conveyance of, or in connexion with, water supplied by the Company, shall communicate with any cistern, butt, or other receptacle used or intended to be used for rain-water.

Stop-valve.

12. Every "communication-pipe" for the conveyance of water to be supplied by the Company into any premises shall have at or near its point of entrance into such premises, and if desired by the consumer within such premises, a sound and suitable stop-valve of the screw-down kind, with an area of water-way not less than that of a half-inch pipe, and not greater than that of the "communication-pipe," the size of the valve within these limits being at the option of the consumer.

If placed in the ground such "stop-valve" shall be protected by a proper cover and "guard-box."

Character of cisterns and ball-taps.

13. Every cistern used in connexion with the water supplied by the Company shall be made and at all times maintained water-tight, and be properly covered and placed in such a position that it may be inspected and cleansed. Every such existing cistern, if not already provided with an efficient "ball-tap," and every such future cistern shall be provided with a sound and suitable "ball-tap" of the valve kind for the inlet of water.

Waste pipes to be removed or converted into warning-pipes.

14. No overflow or waste-pipe other than a "warning-pipe" shall be attached to any cistern supplied with water by the Company, and every such overflow or waste-pipe existing at the time when these regulations come into operation shall be removed, or at the option of the consumer shall be converted into an efficient "warning-pipe," within two calendar months next after the Company shall have given to the occupier of, or left at the premises in which such cistern is situate, a notice in writing requiring such alteration to be made.

Arrangement of warning-pipes.

15. Every "warning-pipe" shall be placed in such a situation as will admit of the discharge of the water from such "warning-pipe" being readily ascertained by the officers of the Company. And the position of such "warning-pipe" shall not be changed without previous notice to and approval by the Company.

Buried cisterns prohibited.

16. No cistern buried or excavated in the ground shall be used for the storage or reception of water supplied by the Company, unless the use of such cistern shall be allowed in writing by the Company.

Butts prohibited.

17. No wooden receptacle without a proper metallic lining shall be hereafter brought into use for the storage of any water supplied by the Company.

Ordinary draw-tap.

18. No draw-tap shall in future be fixed unless the same shall be sound and suitable and of the "screw-down" kind.

Draw-taps in connexion with stand-pipes.

19. Every draw-tap in connexion with any "stand-pipe" or other apparatus outside any dwelling-house in a court or other public place, to supply any group or number of such dwelling-houses, shall be sound and suitable and of the "waste-preventer" kind, and be protected as far as possible from injury by frost, theft, or mischief.

Boilers, watercloseets, and urinals to have cisterns.

20. Every boiler, urinal, and watercloset, in which water supplied by the Company is used (other than waterclosets in which hand flushing is employed), shall, within three months after these regulations come into operation, be served only through a cistern or service-box and without a stool-cock, and there shall be no direct communication from the pipes of the Company to any boiler, urinal, or watercloset.

Watercloset apparatus.

21. Every watercloset-cistern or watercloset service-box hereafter fitted or fixed in which water supplied by the Company is to be used, shall have an efficient waste-preventing apparatus, so constructed as not to be capable of discharging more than two gallons of water at each flush.

Urinal-cistern apparatus.

22. Every urinal-cistern in which water supplied by the Company is used other than public urinal-cisterns, or cisterns having attached to them a self-closing apparatus, shall have an efficient "waste-preventing" apparatus, so constructed as not to be capable of discharging more than one gallon of water at each flush.

Watercloset down-pipes.

23. Every "down-pipe" hereafter fixed for the discharge of water into the pan or basin of any watercloset shall have an internal diameter of not less than one inch and a quarter, and if of lead shall weigh not less than nine pounds to every lineal yard.

Pipes supplying watercloset to communicate with cistern only.

24. No pipe by which water is supplied by the Company to any watercloset shall communicate with any part of such watercloset, or with any apparatus connected therewith, except the service-cistern thereof.

Bath to be without overflow pipe.

25. No bath supplied with water by the Company shall have any overflow waste pipe, except it be so arranged as to act as a "warning-pipe."

Bath apparatus.

26. In every bath hereafter fitted or fixed the outlet shall be distinct from, and unconnected with, the inlet or inlets; and the inlet or inlets must be placed so that the orifice or orifices shall be above the highest water level of the bath. The outlet of every such bath shall be provided with a perfectly water-tight plug, valve, or cock.

Alteration of fittings.

27. No alteration shall be made in any fittings in connexion with the supply of water by the Company without two days' previous notice in writing to the Company.

Waterway of fittings.

28. Except with the written consent of the consumer, no cock, ferrule, joint, union, valve, or other fitting, in the course of any "communication-pipe," shall have a waterway of less area than that of the "communication-pipe," so that the waterway from the water in the district-pipe or other supply-pipe of the Company up to and through the stop-valve prescribed by Regulation No. 12, shall not in any part be of less area than that of the "communication-pipe" itself, which pipe shall not be of less than a half-inch bore in all its course.

Weight of lead pipes having open ends.

29. All lead "warning-pipes" and other lead pipes of which the ends are open, so that such pipes cannot remain charged with water, may be of the following minimum weights, that is to say:—

½-inch	(internal diameter)	- - -	3 lbs. per yard.
¾ „	do.	- - -	5 „
1 „	do.	- - -	7 „

Definition of "communication-pipe."

30. In these Regulations the term "communication-pipe" shall mean the pipe which extends from the district pipe or other supply pipe of the Company up to the "stop-valve" prescribed in the Regulation No. 12.

Penalties.

31. Every person who shall wilfully violate, refuse, or neglect to comply with, or shall wilfully do or cause to be done any act, matter, or thing, in contravention of these Regulations, or any part thereof, shall, for every such offence, be liable to a penalty in a sum not exceeding 5*l.*

Authorised officer may act for company.

32. Where under the foregoing Regulations any act is required or authorised to be done by the Company, the same may be done on behalf of the Company

by an authorised officer or servant of the Company, and where under such Regulations any notice is required to be given by the Company the same shall be sufficiently authenticated if it be signed by an authorised officer or servant of the Company.

33. All existing fittings, which shall be sound and efficient, and are not required to be removed or altered under these Regulations, shall be deemed to be "prescribed fittings" under the "Metropolis Water Act, 1871." *Existing fittings.*

N.B.—Water is wasted in several ways, as by defective works and arrangements, by improper fittings, and by abuse and neglect; proper fittings and sound workmanship will give good works a fair commencement, but subsequent inspection and repairs will be necessary so long as they are in use. It will be found by experience that it is cheaper to supervise and repair the mains and fittings, rather than to allow water to flow to waste.

APPENDIX F. - - - - -

TABLE No. 1.—TABLE showing the equal ANNUAL AMOUNT of PRINCIPAL, combined with INTEREST, Interest, viz., from 3 to 6 per cent. per annum,

[These Tables have been examined by

Number of Years in which loans to be repaid.	3 per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.	3½ per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.	4 per Cent. per Annum. Average Annual Instalment of Principal and Interest of £1.	£100.
1	£ s. d. 1·030000=1 0 7¼	£ s. d. 103 0 0	£ s. d. 1·035000=1 0 8½	£ s. d. 103 10 0	£ s. d. 1·040000=1 0 9½	£ s. d. 104 0 0
2	·522611=0 10 5½	52 5 2¾	·526400=0 10 6¼	52 12 9½	·530196=0 10 7¼	53 0 4¾
3	·353530=0 7 0¾	35 7 0¾	·356934=0 7 1¾	35 13 10¼	·360349=0 7 2½	36 0 8¼
4	·269027=0 5 4¾	26 18 0¾	·272251=0 5 5¼	27 4 6	·275490=0 5 6	27 10 11¾
5	·218354=0 4 4½	21 16 8½	·221481=0 4 5¼	22 2 11½	·224627=0 4 6	22 9 3
6	·184597=0 3 8¼	18 9 2½	·187668=0 3 9	18 15 4	·190762=0 3 9¾	19 1 6¼
7	·160506=0 3 2½	16 1 0¼	·163544=0 3 3¼	16 7 1	·166610=0 3 4	16 13 2½
8	·142456=0 2 10¾	14 4 11	·145477=0 2 11	14 10 11¼	·148528=0 2 11¾	14 17 0¾
9	·128434=0 2 6¾	12 16 10½	·131446=0 2 7½	13 2 10¾	·134493=0 2 8¼	13 8 11¾
10	·117231=0 2 4¼	11 14 5½	·120241=0 2 4¾	12 0 5¾	·123291=0 2 5½	12 6 7
11	·108077=0 2 2	10 16 1¾	·111092=0 2 2¾	11 2 2¼	·114149=0 2 3½	11 8 3½
12	·100462=0 2 0	10 0 11	·103484=0 2 0¾	10 6 11¾	·106552=0 2 1½	10 13 1¼
13	·094030=0 1 10½	9 8 0¾	·097062=0 1 11¼	9 14 1½	·100144=0 2 0	10 0 3½
14	·088526=0 1 9¼	8 17 0½	·091571=0 1 10	9 3 1¾	·094669=0 1 10¾	9 9 4
15	·083767=0 1 8	8 7 6¼	·086825=0 1 8¾	8 13 7¾	·089941=0 1 9½	8 19 10½
16	·079611=0 1 7¼	7 19 2¾	·082685=0 1 7¾	8 5 4½	·085820=0 1 8½	8 11 7¾
17	·075953=0 1 6¼	7 11 10¾	·079043=0 1 7	7 18 1	·082199=0 1 7¾	8 4 4¾
18	·072709=0 1 5½	7 5 5	·075817=0 1 6¼	7 11 7½	·078993=0 1 7	7 17 11¾
19	·069814=0 1 4¾	6 19 7½	·072940=0 1 5½	7 5 10½	·076139=0 1 6¼	7 12 3¼
20	·067216=0 1 4¼	6 14 5¼	·070361=0 1 5	7 0 8¾	·073582=0 1 5¾	7 7 2
21	·064872=0 1 3½	6 9 9	·068037=0 1 4¼	6 16 1	·071280=0 1 5	7 2 6¾
22	·062747=0 1 3	6 5 6	·065932=0 1 3¾	6 11 10¼	·069199=0 1 4½	6 18 4¾
23	·060814=0 1 2½	6 1 7½	·064019=0 1 3¼	6 8 0½	·067309=0 1 4¼	6 14 7½
24	·059047=0 1 2¼	5 18 1¼	·062273=0 1 3	6 4 6½	·065587=0 1 3¾	6 11 2
25	·057428=0 1 1¾	5 14 10¼	·060674=0 1 2½	6 1 4¼	·064012=0 1 3¼	6 8 0¼
26	·055938=0 1 1½	5 11 10½	·059205=0 1 2¼	5 18 5	·062567=0 1 3	6 5 1½
27	·054564=0 1 1	5 9 1½	·057852=0 1 2	5 15 8½	·061239=0 1 2¾	6 2 5½
28	·053293=0 1 0¾	5 6 7	·056603=0 1 1½	5 13 2½	·060013=0 1 2½	6 0 0¼
29	·052115=0 1 0½	5 4 2¾	·055445=0 1 1¼	5 10 10¾	·058880=0 1 2	5 17 7¼
30	·051019=0 1 0¼	5 2 0½	·054371=0 1 1	5 8 9	·057830=0 1 1¾	5 15 8
31	·049999=0 1 0	5 0 0	·053372=0 1 0¾	5 6 9	·056855=0 1 1¾	5 13 8½
32	·049047=0 0 11¾	4 18 1	·052442=0 1 0½	5 4 10¾	·055949=0 1 1½	5 11 10¾
33	·048156=0 0 11½	4 16 3¾	·051572=0 1 0½	5 3 1¾	·055104=0 1 1¼	5 10 2½
34	·047322=0 0 11¼	4 14 7¾	·050760=0 1 0¼	5 1 6¼	·054315=0 1 1	5 8 7½
35	·046539=0 0 11¼	4 13 1	·049998=0 1 0	5 0 0	·053577=0 1 0¾	5 7 1¾
36	·045804=0 0 11	4 11 7¼	·049284=0 0 11¾	4 18 6¾	·052887=0 1 0¾	5 5 9¼
37	·045112=0 0 10¾	4 10 2¾	·048613=0 0 11¾	4 17 2¾	·052240=0 1 0½	5 4 5¾
38	·044459=0 0 10¾	4 8 11	·047982=0 0 11½	4 15 11½	·051632=0 1 0½	5 3 3¼
39	·043844=0 0 10½	4 7 8¼	·047388=0 0 11½	4 14 9¼	·051061=0 1 0¼	5 2 1½
40	·043262=0 0 10½	4 6 6¼	·046827=0 0 11¼	4 13 7¾	·050524=0 1 0¼	5 1 0½
41	·042712=0 0 10¼	4 5 5	·046298=0 0 11¼	4 12 7	·050017=0 1 0	5 0 0½
42	·042192=0 0 10¼	4 4 4¾	·045798=0 0 11	4 11 7¼	·049540=0 1 0	4 19 1
43	·041698=0 0 10	4 3 4¾	·045325=0 0 11	4 10 7¾	·049090=0 0 11¾	4 18 2¼
44	·041230=0 0 10	4 2 5½	·044878=0 0 10¾	4 9 9	·048665=0 0 11¾	4 17 4
45	·040785=0 0 9¾	4 1 6¾	·044453=0 0 10¾	4 8 11	·048263=0 0 11½	4 16 6¼
46	·040363=0 0 9¾	4 0 8¾	·044051=0 0 10½	4 8 1¼	·047882=0 0 11½	4 15 9¼
47	·039961=0 0 9½	3 19 11	·043669=0 0 10½	4 7 4	·047522=0 0 11½	4 15 0½
48	·039578=0 0 9½	3 19 2	·043307=0 0 10½	4 6 7¼	·047181=0 0 11¼	4 14 4¼
49	·039213=0 0 9½	3 18 5	·042962=0 0 10¼	4 5 11	·046857=0 0 11¼	4 13 8½
50	·038866=0 0 9¼	3 17 8¾	·042634=0 0 10¼	4 5 3¼	·046550=0 0 11¼	4 13 1¼

Rule.—To find the Annual Instalment to repay any amount with Interest in any number of Years from 1 to 50, at any rate of Interest from 3 to 6 per cent., multiply the sum to be repaid with Interest in equal Annual Instalments by the fraction of 1*l.*, which would repay 1*l.*, with Interest at the given rate in the given period, as shown in the first column of the Table opposite the number of Years.

Example:—To find the Annual Instalment to repay 5,722*l.* with Interest at 4½ per cent. per annum in 23 equal Annual Instalments.

1st Method:—

·070682 × £5,722 = £404 8 10

or ·070682

5722

141364
141364
494774
353410

404·442404
20

8·848080
12

10·176960 = £404 8 10

APPENDIX F.

which is requisite for the REPAYMENT of LOANS, at the under-mentioned rates of in any period from one to fifty years.

the Actuary of the National Debt Office.]

4½ per Cent. per Annum.						5 per Cent. per Annum.						6 per Cent. per Annum.						Number of Years in which Loans to be repaid.
Average Annual Instalment of Principal and Interest of						Average Annual Instalment of Principal and Interest of						Average Annual Instalment of Principal and Interest of						
£1.			£100.			£1.			£100.			£1.			£100.			
£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	
1·045000=1	0	10¾	104	10	0	1·050000=1	1	0	105	0	0	1·060000=1	1	2½	106	0	0	1
·533998=0	10	8¼	53	8	0	·537805=0	10	9	53	15	7¼	·545437=0	10	11	54	10	10½	2
·363773=0	7	3¼	36	7	6½	·367209=0	7	4¼	36	14	5	·374110=0	7	5¾	37	8	2¾	3
·278744=0	5	7	27	17	5¾	·282012=0	5	7¾	28	4	0¾	·288591=0	5	9½	28	17	2¼	4
·227792=0	4	6¾	22	15	7	·230975=0	4	7½	23	1	11½	·237396=0	4	9	23	14	9½	5
·193878=0	3	10½	19	7	9	·197017=0	3	11¼	19	14	0¼	·203366=0	4	0¾	20	6	8¾	6
·169701=0	3	4¾	16	19	5	·172820=0	3	5½	17	5	7¾	·179135=0	3	7	17	18	3¼	7
·151610=0	3	0½	15	3	2¾	·154722=0	3	1	15	9	5½	·161036=0	3	2¾	16	2	0¾	8
·137574=0	2	9	13	15	1¾	·140690=0	2	9¾	14	1	4½	·147022=0	2	11¼	14	14	0½	9
·126379=0	2	6¼	12	12	9	·129505=0	2	7	12	19	0	·135868=0	2	8¾	13	11	9	10
·117248=0	2	4¼	11	14	6	·120389=0	2	5	12	0	9¼	·126793=0	2	6¼	12	13	7	11
·109666=0	2	2¼	10	19	4	·112825=0	2	3	11	5	7¾	·119277=0	2	4¾	11	18	6¾	12
·103275=0	2	0¾	10	6	6½	·106456=0	2	1½	10	12	11	·112960=0	2	3	11	5	11	13
·097820=0	1	11½	9	15	7¾	·101024=0	2	0¼	10	2	0½	·107585=0	2	1¾	10	15	2	14
·093114=0	1	10¼	9	6	2¾	·096342=0	1	11¼	9	12	8¼	·102963=0	2	0¾	10	5	11¼	15
·089015=0	1	9½	8	18	0¼	·092270=0	1	10¾	9	4	6½	·098952=0	1	11¾	9	17	11	16
·085418=0	1	8½	8	10	10	·088699=0	1	9¾	8	17	4¾	·095445=0	1	11	9	10	10¾	17
·082237=0	1	7¾	8	4	5¾	·085546=0	1	8½	8	11	1	·092357=0	1	10¼	9	4	8½	18
·079407=0	1	7	7	18	9¾	·082745=0	1	7¾	8	5	5¾	·089621=0	1	9½	8	19	3	19
·076876=0	1	6½	7	13	9	·080243=0	1	7¼	8	0	5¾	·087185=0	1	9	8	14	4½	20
·074601=0	1	6	7	9	2½	·077996=0	1	6¾	7	16	0	·085005=0	1	8½	8	10	0	21
·072546=0	1	5½	7	5	1	·075971=0	1	6¼	7	11	11½	·083046=0	1	8	8	6	1	22
·070682=0	1	5	7	1	4¼	·074137=0	1	5¾	7	8	3½	·081278=0	1	7½	8	2	6¾	23
·068987=0	1	4½	6	17	11¾	·072471=0	1	5½	7	4	11¼	·079679=0	1	7¼	7	19	4¼	24
·067439=0	1	4¼	6	14	10½	·070952=0	1	5	7	1	11	·078227=0	1	6¾	7	16	5½	25
·066021=0	1	4	6	12	0½	·069564=0	1	4¾	6	19	1½	·076904=0	1	6½	7	13	9¾	26
·064719=0	1	3½	6	9	5¼	·068292=0	1	4½	6	16	7	·075697=0	1	6¼	7	11	4¾	27
·063521=0	1	3¼	6	7	0½	·067123=0	1	4¼	6	14	3	·074593=0	1	6	7	9	2¼	28
·062415=0	1	3	6	4	10	·066046=0	1	4	6	12	1	·073580=0	1	5¾	7	7	2	29
·061392=0	1	2¾	6	2	9½	·065051=0	1	3¾	6	10	1¼	·072649=0	1	5½	7	5	3½	30
·060443=0	1	2½	6	0	10¾	·064132=0	1	3½	6	8	3¼	·071792=0	1	5¼	7	3	7	31
·059563=0	1	2¼	5	19	1½	·063280=0	1	3¼	6	6	6¾	·071002=0	1	5	7	2	0	32
·058745=0	1	2	5	17	6	·062490=0	1	3	6	4	11¾	·070273=0	1	4¾	7	0	6½	33
·057982=0	1	2	5	15	11½	·061755=0	1	2¾	6	3	6	·069598=0	1	4¾	6	19	2¼	34
·057270=0	1	1¾	5	14	6½	·061072=0	1	2¾	6	2	1¾	·068974=0	1	4½	6	17	11½	35
·056606=0	1	1½	5	13	2½	·060435=0	1	2½	6	0	10½	·068395=0	1	4½	6	16	9½	36
·055984=0	1	1½	5	11	11¾	·059840=0	1	2¼	5	19	8¼	·067857=0	1	4¼	6	15	8½	37
·055402=0	1	1¼	5	10	9¾	·059284=0	1	2¼	5	18	6¾	·067358=0	1	4¼	6	14	8½	38
·054856=0	1	1¼	5	9	8½	·058765=0	1	2	5	17	6½	·066894=0	1	4	6	13	9½	39
·054343=0	1	1	5	8	8¼	·058278=0	1	2	5	16	6¾	·066462=0	1	4	6	12	11	40
·053862=0	1	1	5	7	8¾	·057822=0	1	2	5	15	7¾	·066059=0	1	4	6	12	1½	41
·053409=0	1	0¾	5	6	9¾	·057395=0	1	1¾	5	14	9½	·065683=0	1	3¾	6	11	4½	42
·052982=0	1	0¾	5	5	11½	·056993=0	1	1¾	5	13	11¾	·065333=0	1	3¾	6	10	8	43
·052581=0	1	0¾	5	5	2	·056616=0	1	1½	5	13	2¾	·065006=0	1	3½	6	10	0¼	44
·052202=0	1	0½	5	4	5	·056262=0	1	1½	5	12	6¼	·064701=0	1	3½	6	9	4¾	45
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·051507=0	1	0½	5	3	0¼	·055614=0	1	1¼	5	11	2¾	·064148=0	1	3½	6	8	3½	47
·051189=0	1	0¼	5	2	4½	·055318=0	1	1¼	5	10	7¾	·063898=0	1	3¼	6	7	9½	48
·050887=0	1	0¼	5	1	9¼	·055040=0	1	1¼	5	10	1	·063664=0	1	3¼	6	7	4	49
·050602=0	1	0¼	5	1	2½	·054777=0	1	1¼	5	9	6¾	·063444=0	1	3¼	6	6	10¾	50

Or less exactly by proportion in sterling money,—as 100*l.* is to the sum to be repaid, so is the Annual Instalment which would repay 100*l.* in the given period, with the given rate of Interest, to the Annual Instalment required. The Instalment necessary to repay 100*l.* is shown in the third column opposite the given number of Years.

***2d Method*:—** As £100 : £5,722 : : £7 1 4¼ : £404 8 3¼

20

141

12

1696

4

6785

5722

13570

13570

47495

33925

100)388237(70

4)388237

12)97059–¼

20)8088–3

£404 8 3¼

DESCRIPTIONS OF THE SPECIMEN PLANS, SECTIONS, AND DIAGRAMS, Nos. 1 to 18.

Plan No.

1 PLAN showing sewers, manholes, and lampholes, on a scale of $\frac{1}{2500}$th, laid out in accordance with the printed Suggestions. See pages 6–18.

2 PLAN showing details at Ordnance scale 10 ft. to 1 mile.

3 GENERAL PLAN, scale 24 inches to 1 mile.

4 PLAN OF MANHOLE DETAILS.

5 Cross sections of brick-sewers with prices per lineal yard.

6 Specimen plan for side entrance, with details.

7 Plan of main-sewer junction, showing side entrance.

8 Side-junction, small main-sewer into large main-sewer.

9 Double earthenware pipe-sewers, joining brick barrel-sewer.

10 Valve-chamber, with flap valve, over sewer end, and sewer ventilating shaft.

11 Junction of earthenware pipe-sewer into egg-shaped brick sewer, manhole-shaft and side-chamber for sewer ventilation.

12 Junction of earthenware pipe-sewers with manhole-shaft, and side chambers for ventilation.

13 Valve-chamber and ventilating side-chamber, showing flap-cover to end of sewer.

14 Longitudinal section of outlet-sewer on sea shore, or tidal river, showing manhole and ventilation chamber, flap tidal-valve over the end of the outlet-sewer with cast-iron pipe to be carried into and below low water.

15 Sketch specimen plans for service-tanks of brick, and of cast-iron.

16 Plan, section, and details of sand-filters.

17 Penstock and tidal flap-valve for brick sewers.

18 Self acting overflow-valve and tidal flap-valves for sewers.

LONDON:
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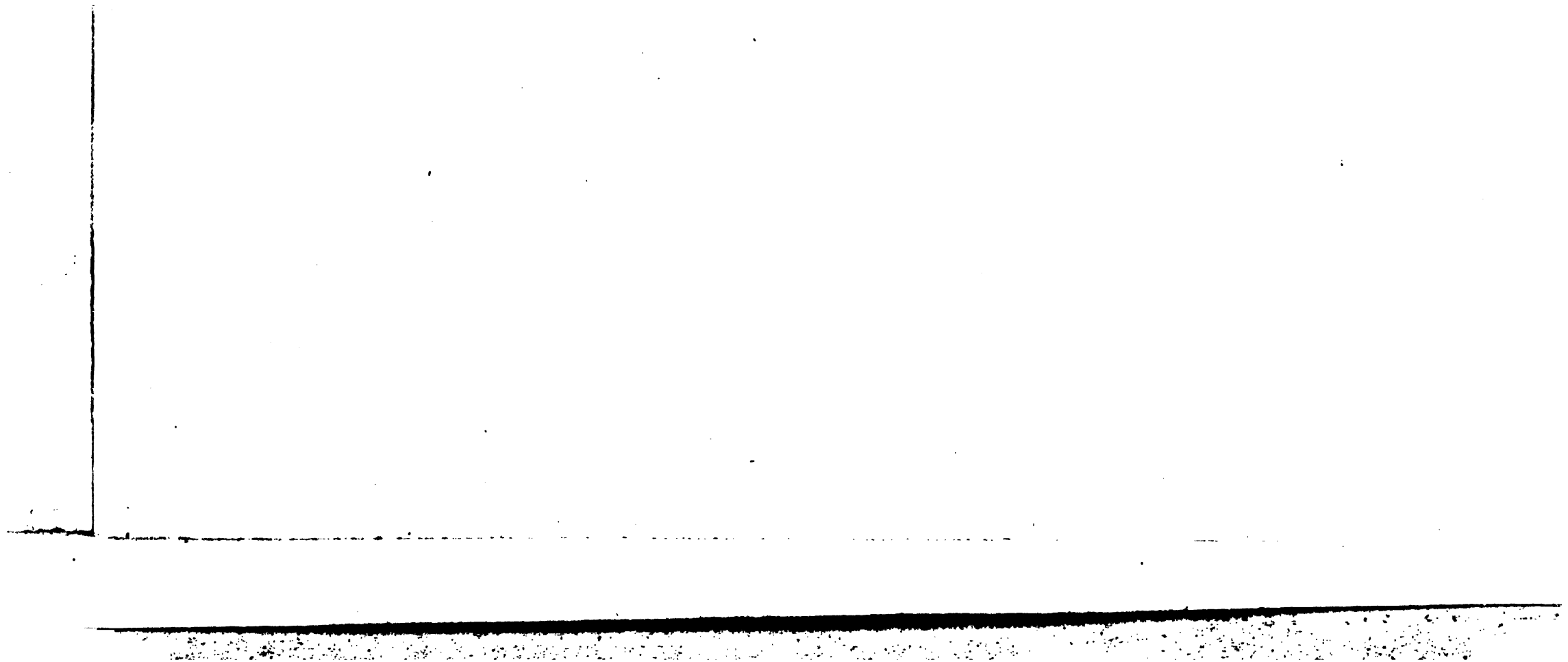
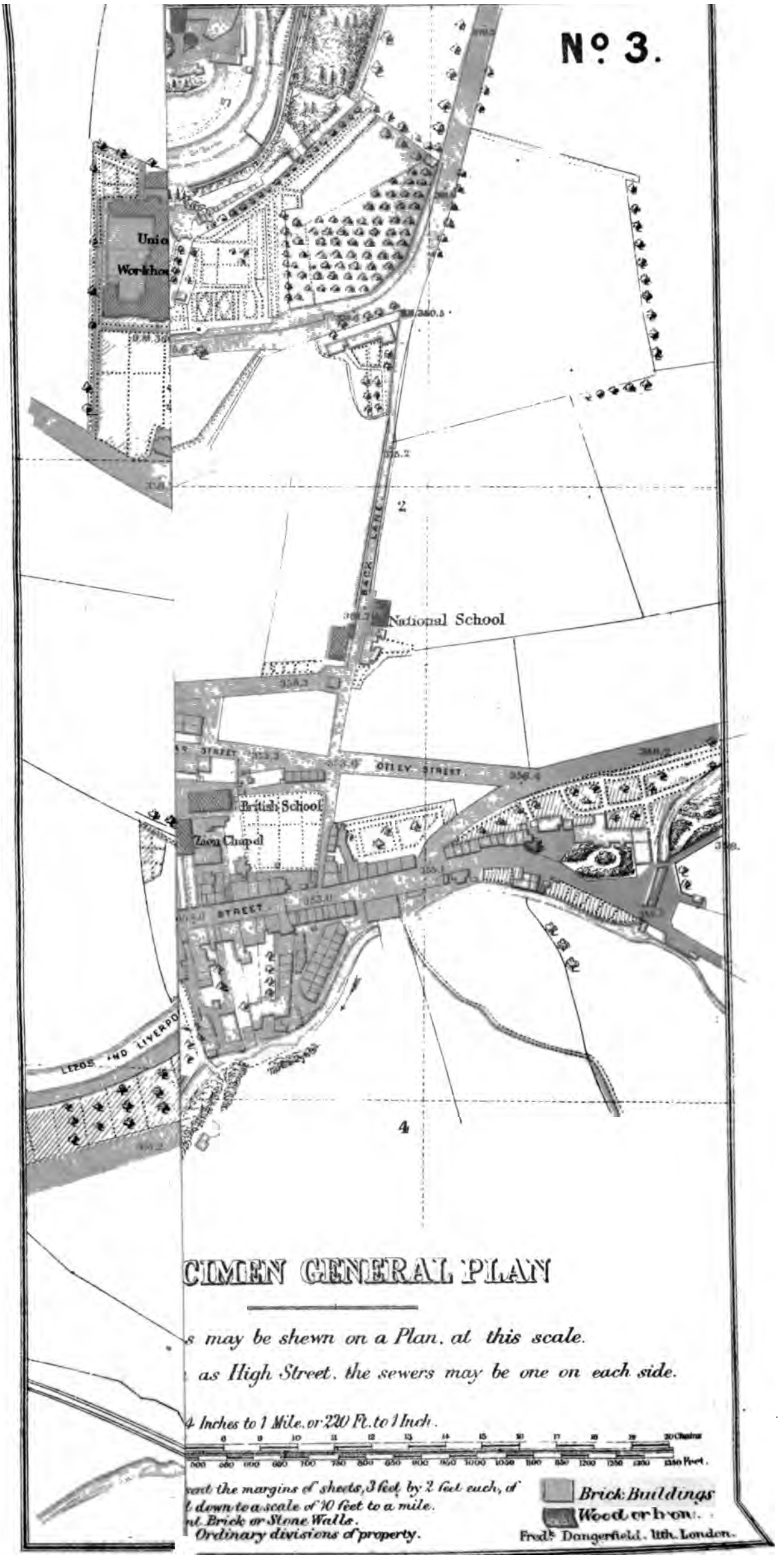
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.
[B 883.—5000.—12/78.]

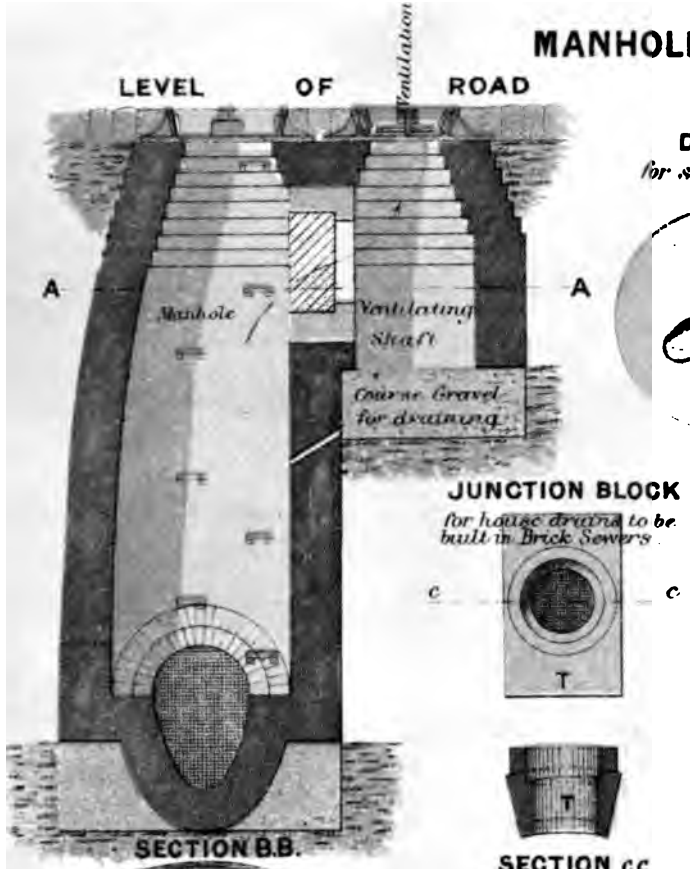


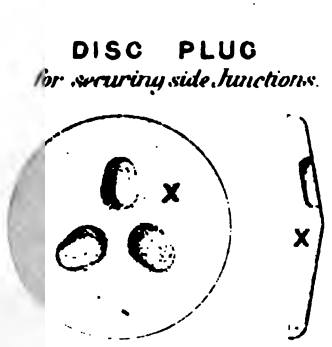

Nº 3.
Union Workhouse
BACK LANE
National School
OTLEY STREET
British School
Zion Chapel
STREET
LEEDS AND LIVERPOOL CANAL
2
4
CIMEN GENERAL PLAN
s may be shewn on a Plan, at this scale.
as High Street, the sewers may be one on each side.
4 Inches to 1 Mile, or 220 Ft. to 1 Inch.
Chains
Feet
vent the margins of sheets, 3 feet by 2 feet each, of
down to a scale of 10 feet to a mile.
nd Brick or Stone Walls.
Ordinary divisions of property.
Brick Buildings
Wood or Iron.
Fredk Dangerfield, lith. London.

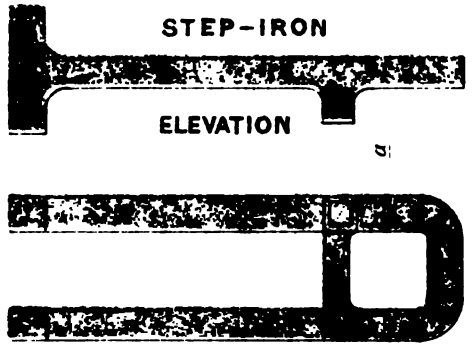
The Sanitary Acts. Specimen Plan of Details of

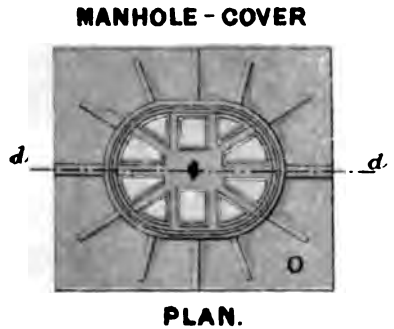
MANHOLE & VENTILATING SHAFT ON BRICK SEWER.

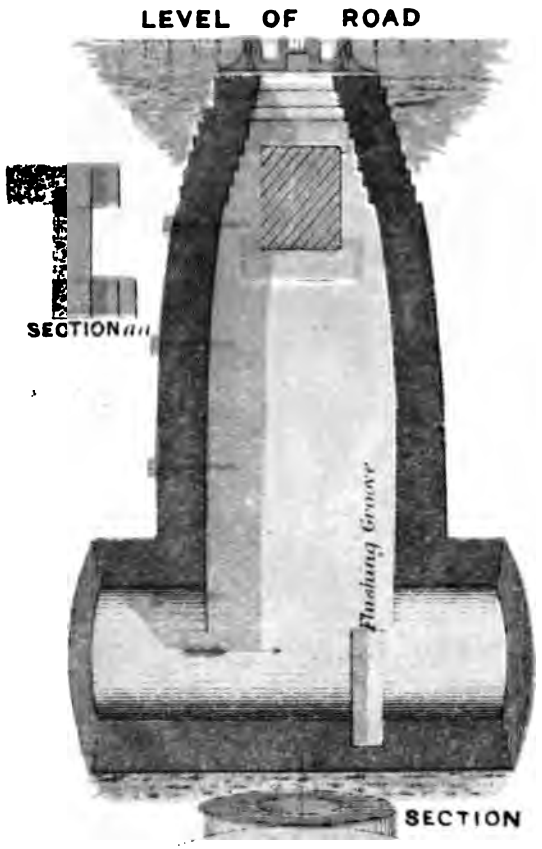
Sewerage. **No. 4.**











SCALE FOR DETAILS.

XXXX	*Step-Iron and Disc-Plug*	*2 ins to a foot.*
TT	*Junction-Block.*	*¾ to a foot*
OOO	*Manhole Cover & Ventilating Grate*	*½ to a foot.*

SCALE OF FEET.

for Plans & Sections of Manhole &c

But 12 . 0 . 1 . 2 . 3 . 4 . 5 . 6 . 7 . 8 . 9 . 10 Feet

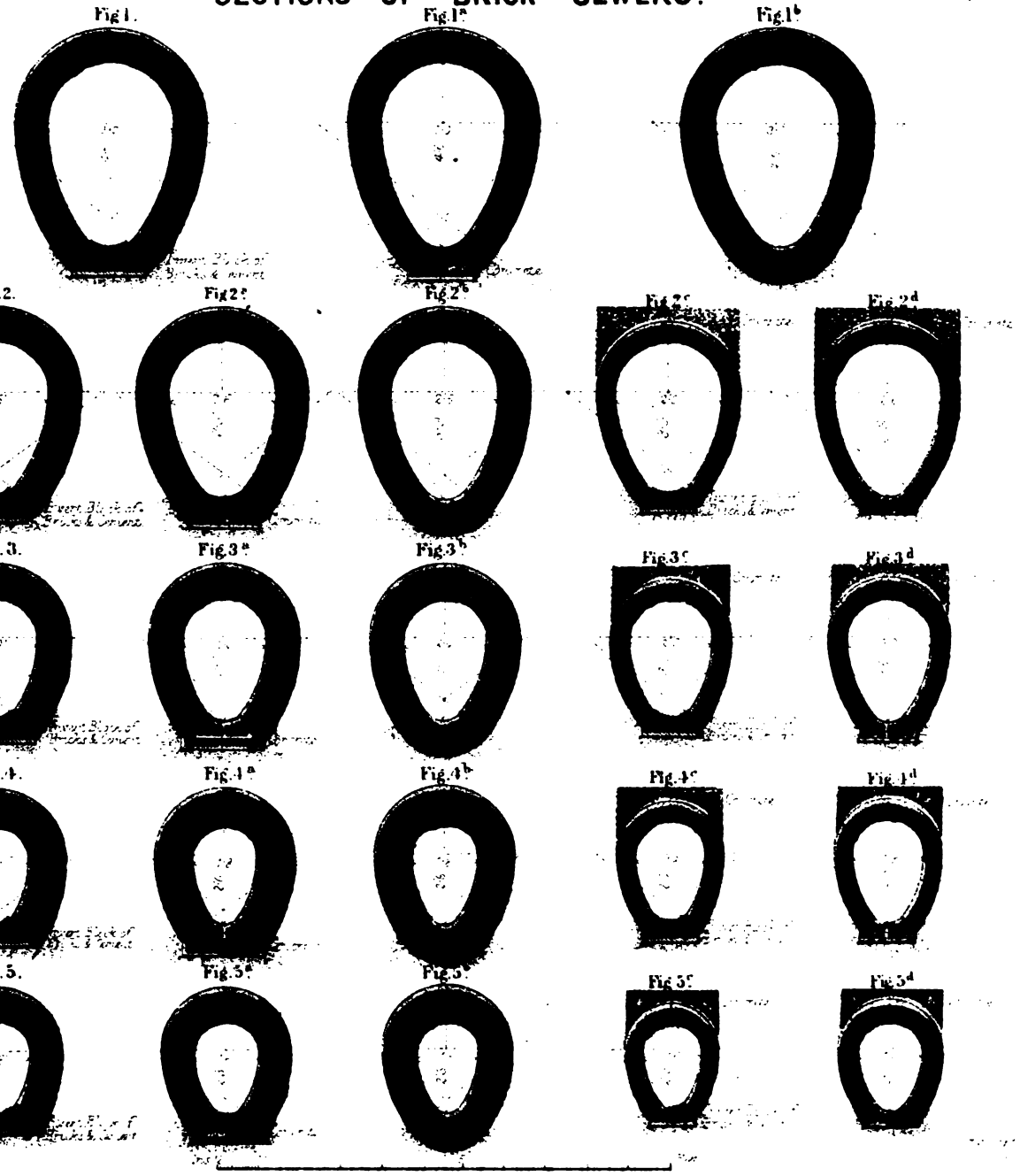
Robert Rawlinson C.E.

Specimen Plan.

SECTIONS OF BRICK SEWERS.

Sewerage Works.

Nº 5.



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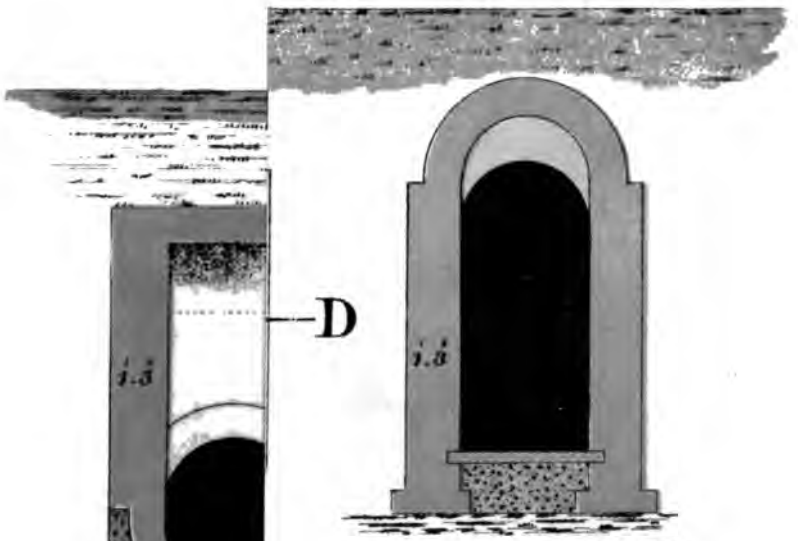
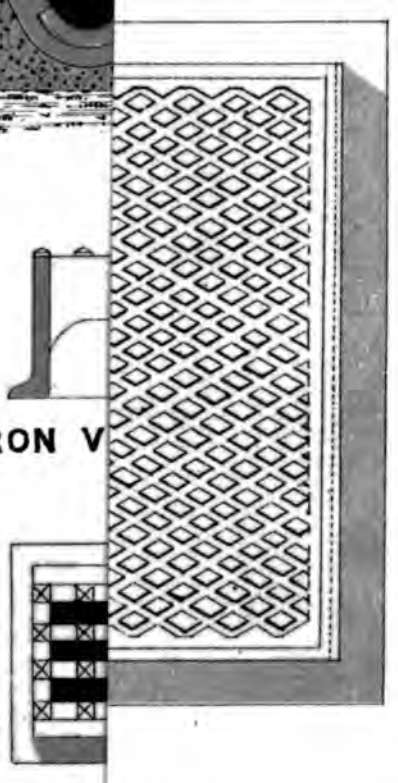
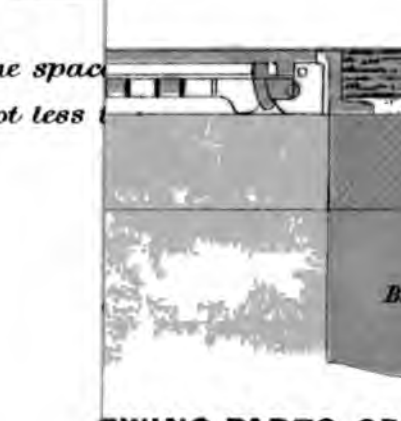


SECTION A.B.



IRON V



N.B. The spac
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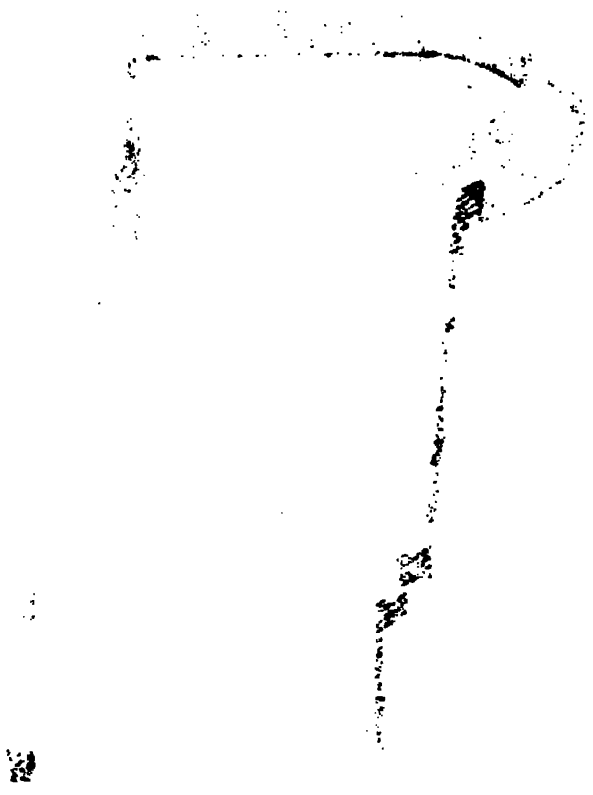
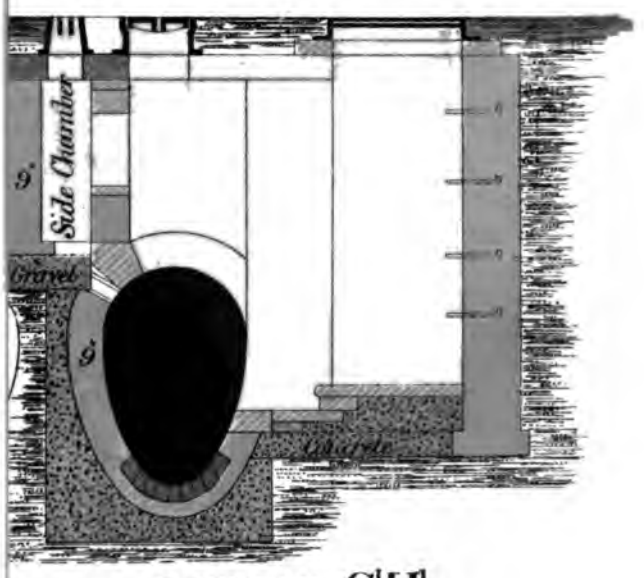
EWING PARTS OF UPPER
WER SAFETY-GRATE.

STEP-IRONS
FOR SHAFTS.

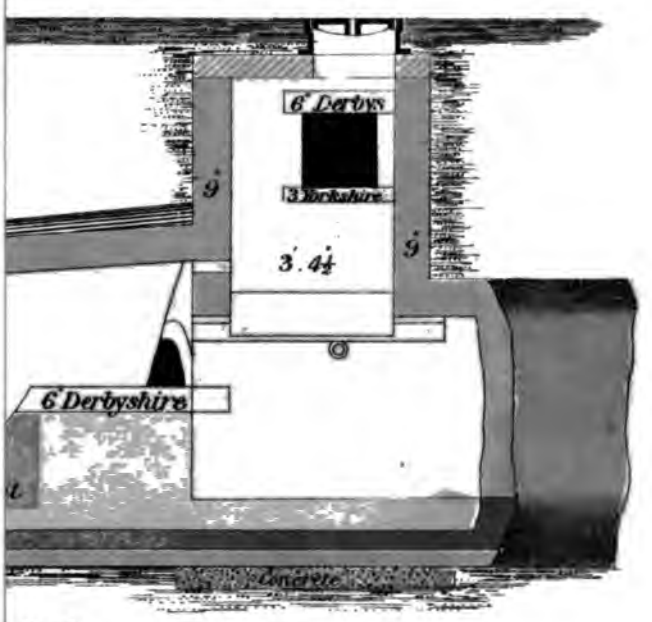


N°7.

TRANCE.



SECTION G.H.



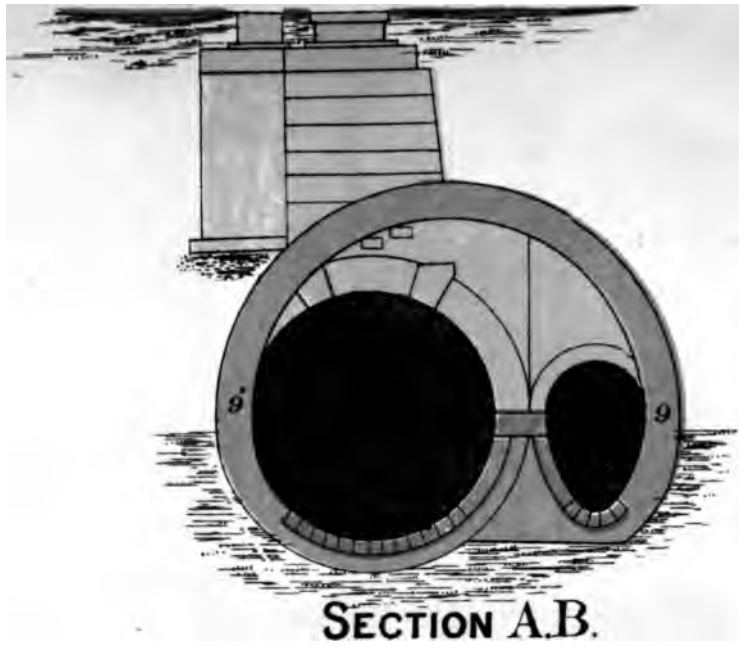
C.D.

25 Feet.

Dangerfield Lith 22, Berners St Oxford Street

Nº 8.

Side-Junction 3'.0".x 2'.0". into 5'.0". barrel.



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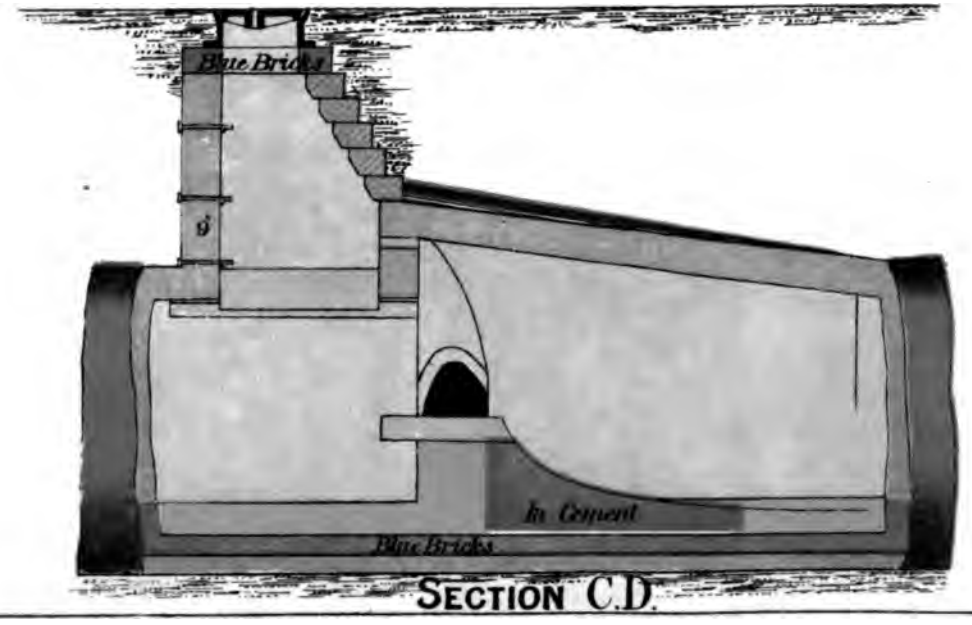

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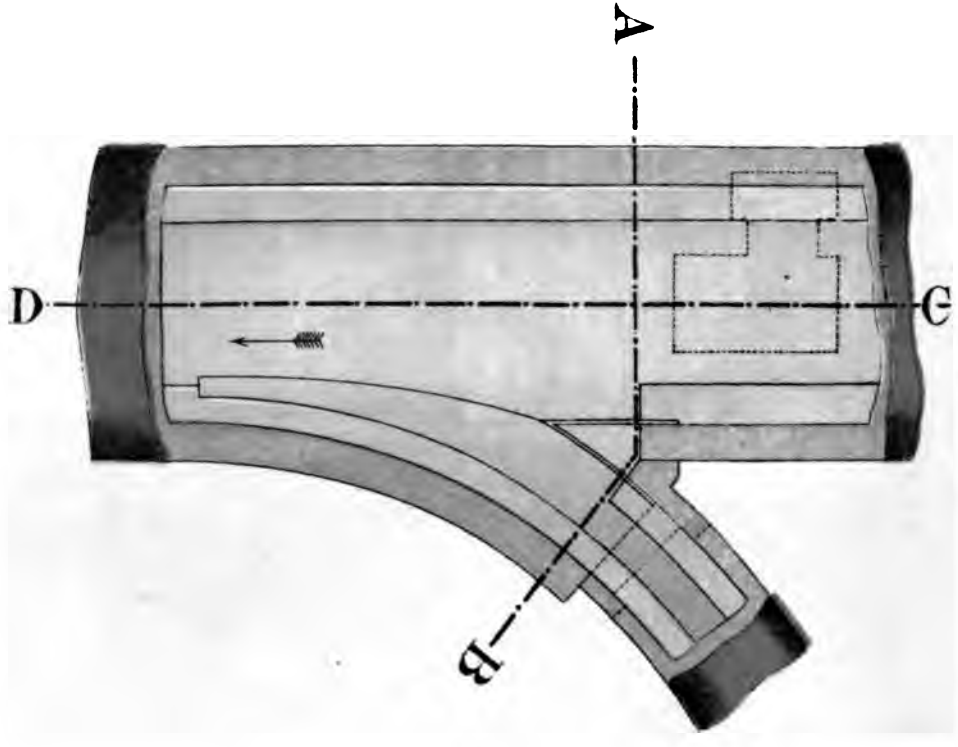
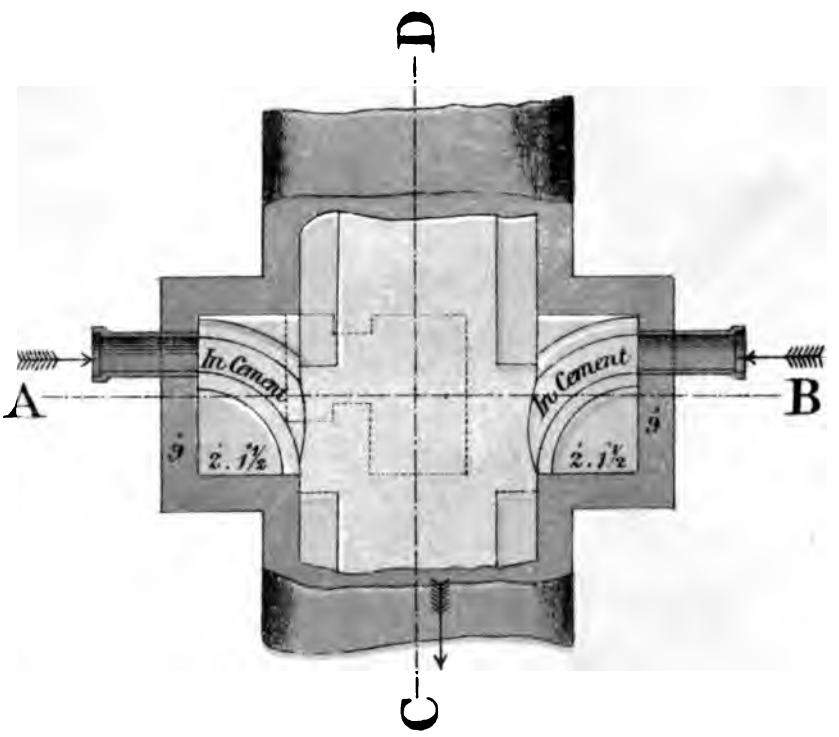
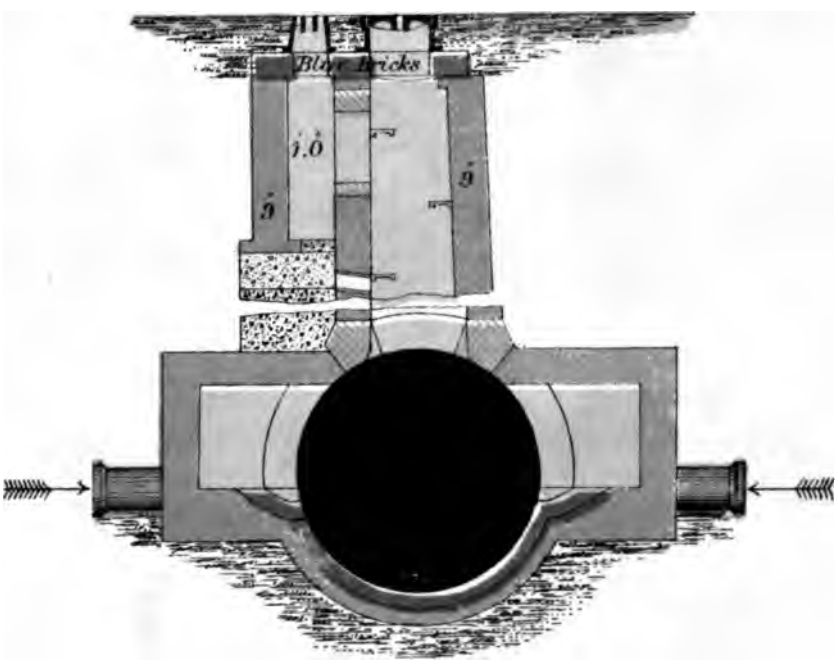


Dangerfield's Lith. 21. Bedford S. Covent Garden.

9′ Double Pipe into 5′.0′ Barrel. No 9





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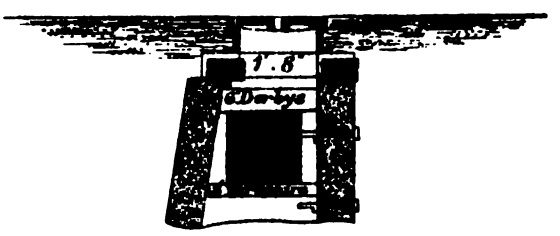

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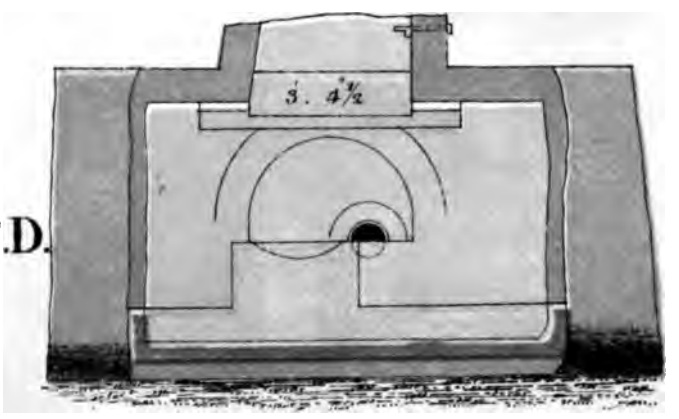
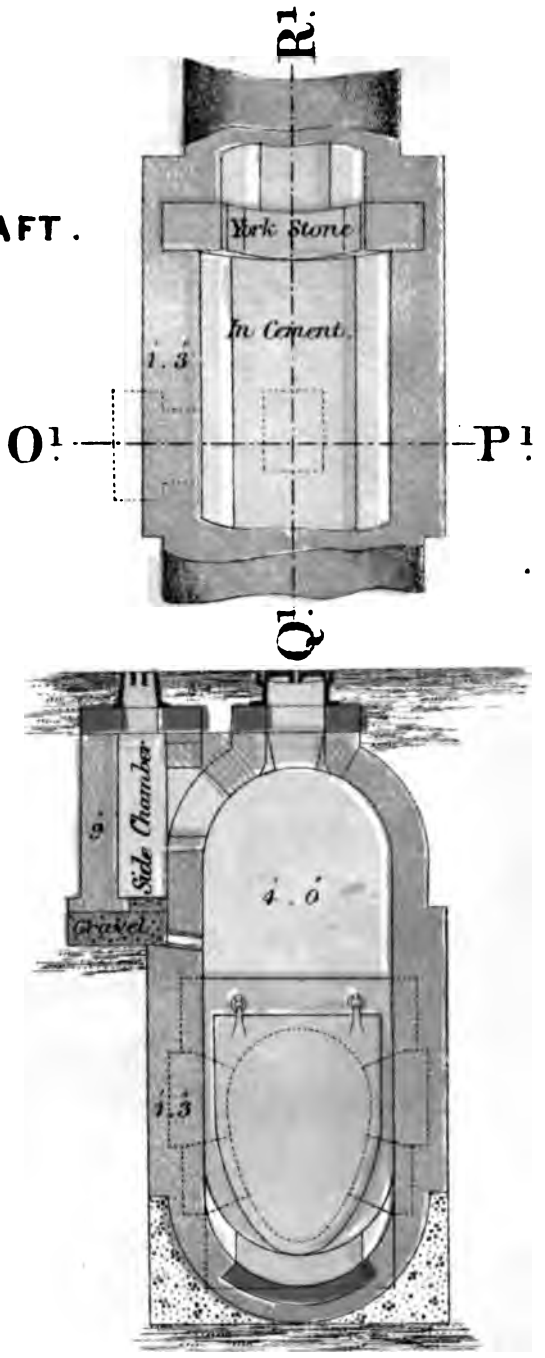


VALVE–CHAMBER AND VENTILATION–SHAFT.

Nº 10.



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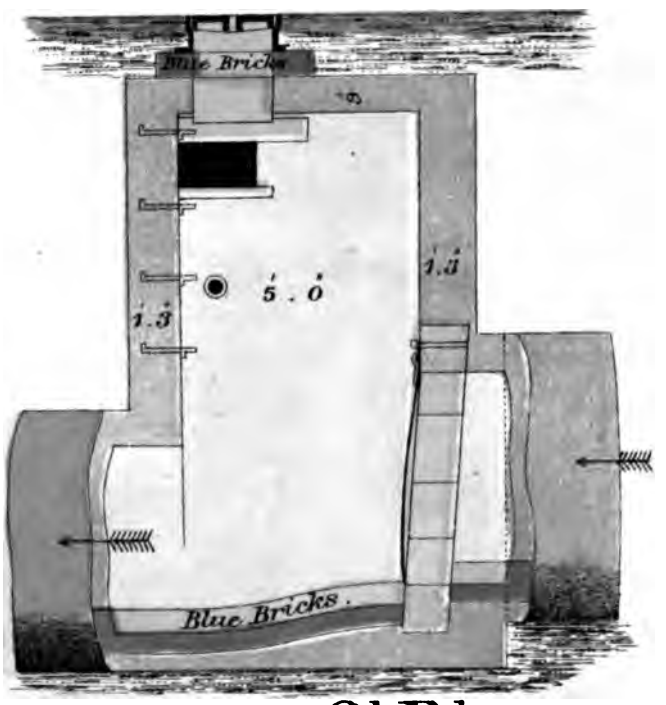

SECTION Q¹ R¹.

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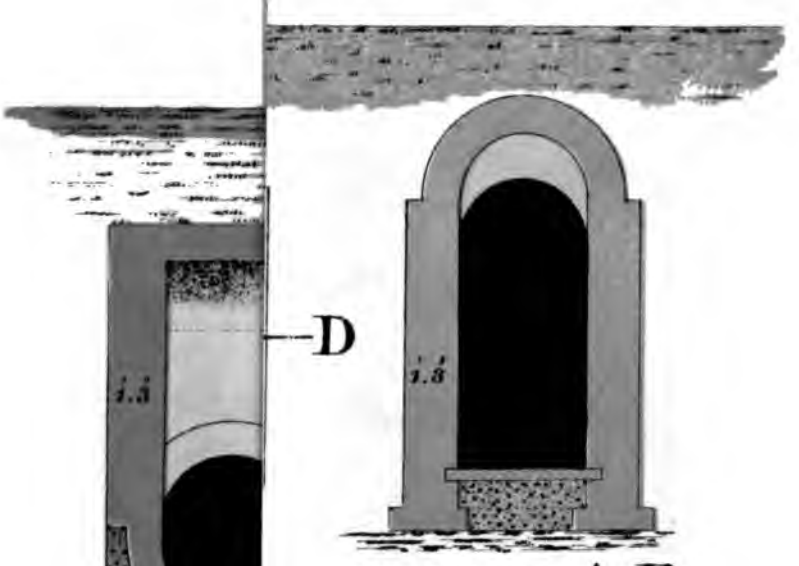

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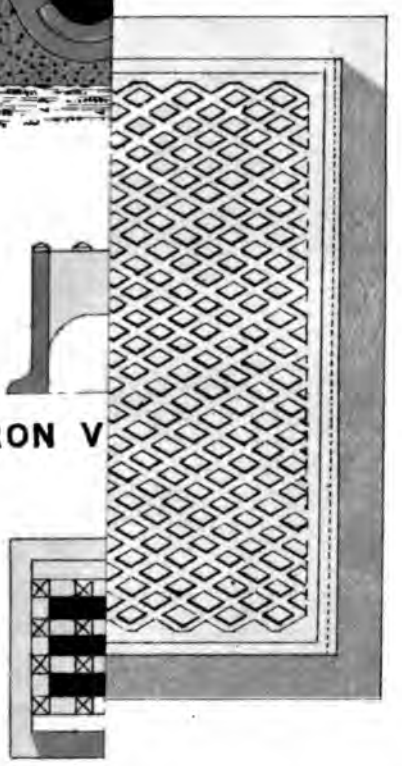
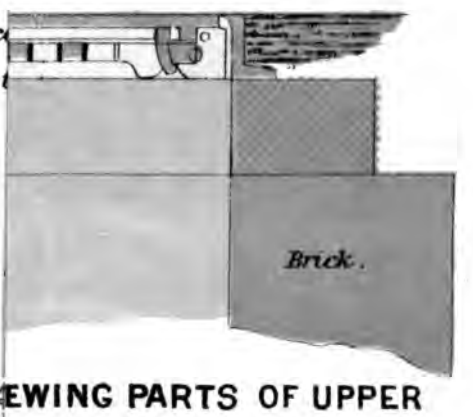


IRON V



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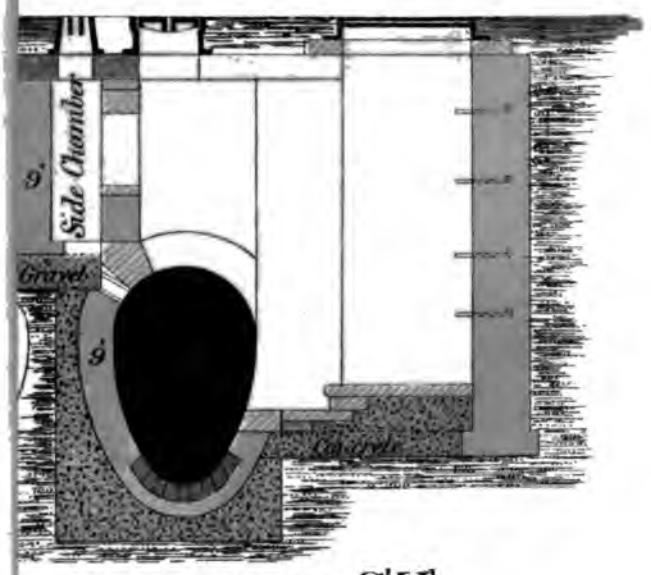
STEP-IRONS
FOR SHAFTS.

TRANCE.



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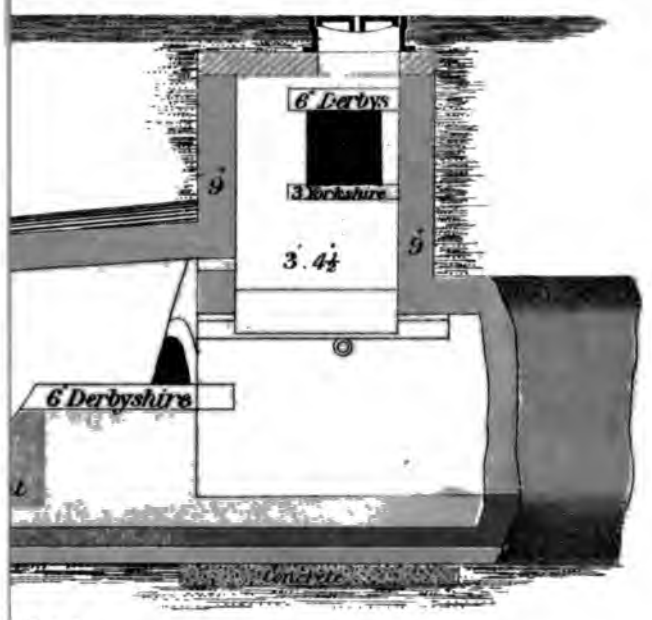
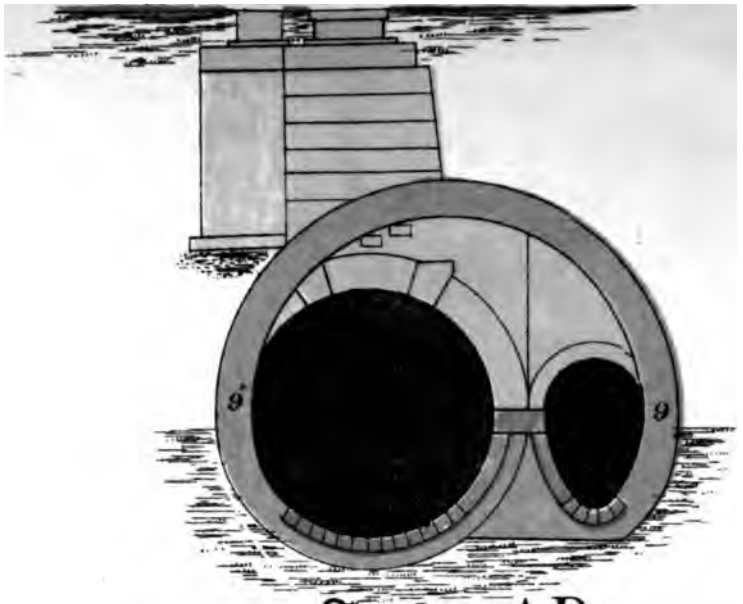


C.D.

25 Feet.

Dangerfield Lith. 29. Bedford St Covent Garden

SIDE-JUNCTION 3'.0".x 2'.0". INTO 5'.0". BARREL.



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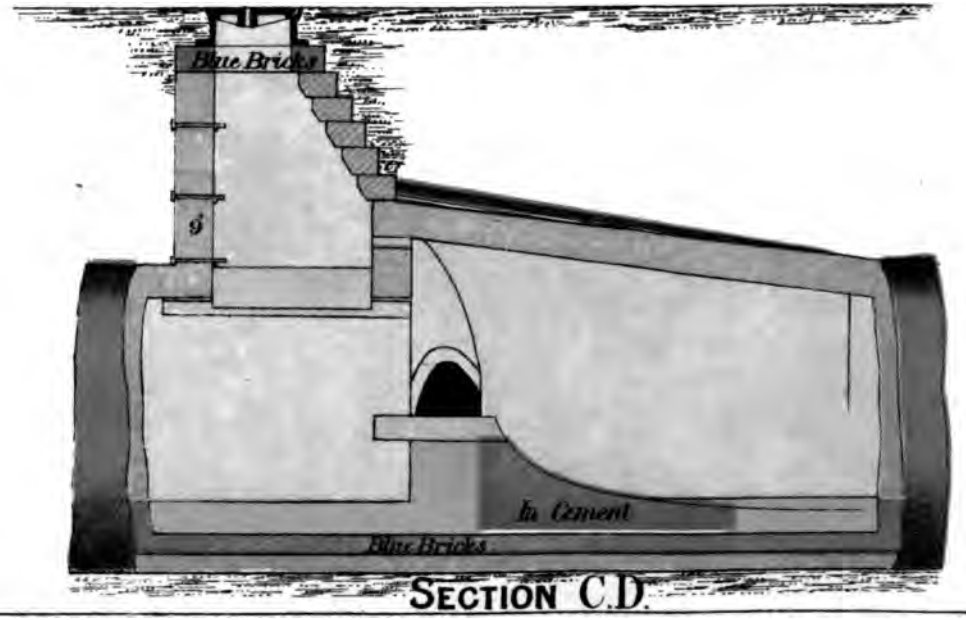
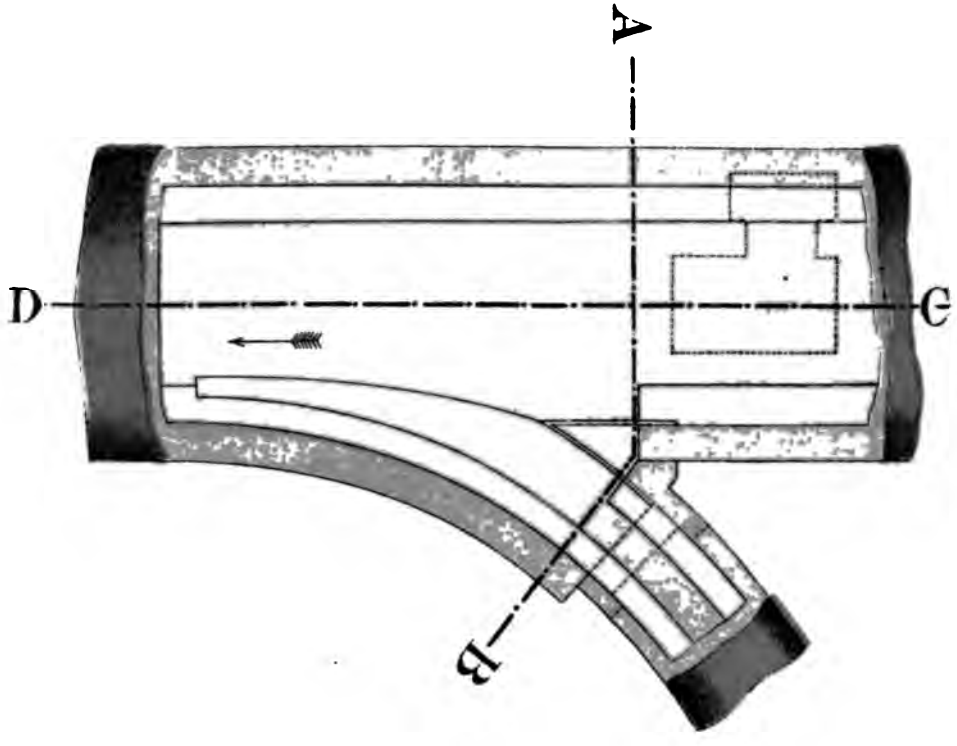


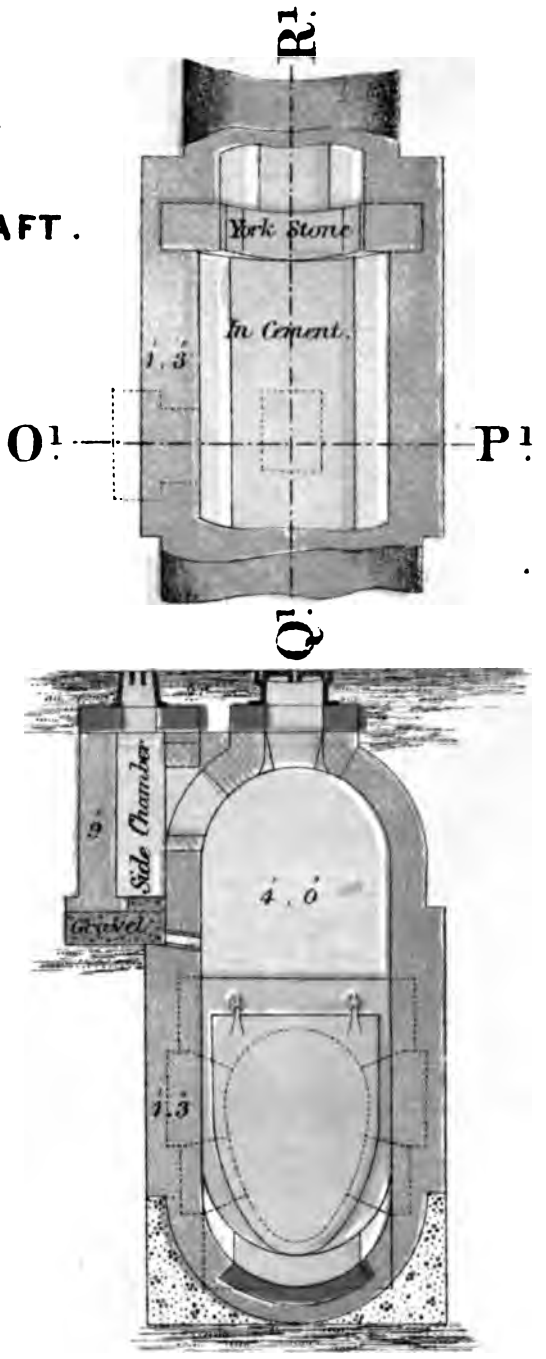
SECTION C.D.



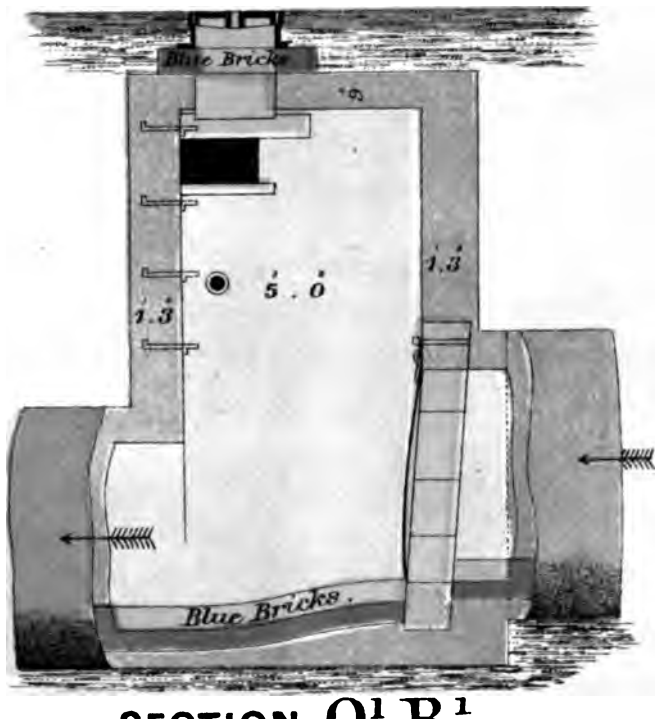
DANCKERTS LITH. 21, BEDFORD ST. COVENT GARDEN.

VALVE–CHAMBER AND VENTILATION–SHAFT.

Nº 10.



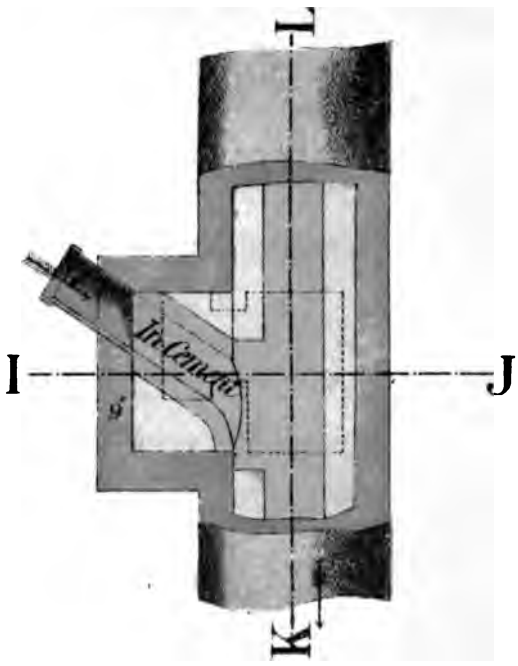
SECTION . O¹ P¹.

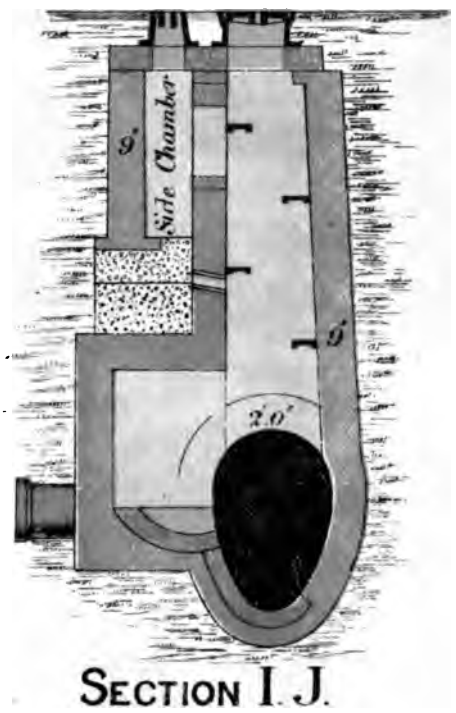


SECTION Q¹ R¹.

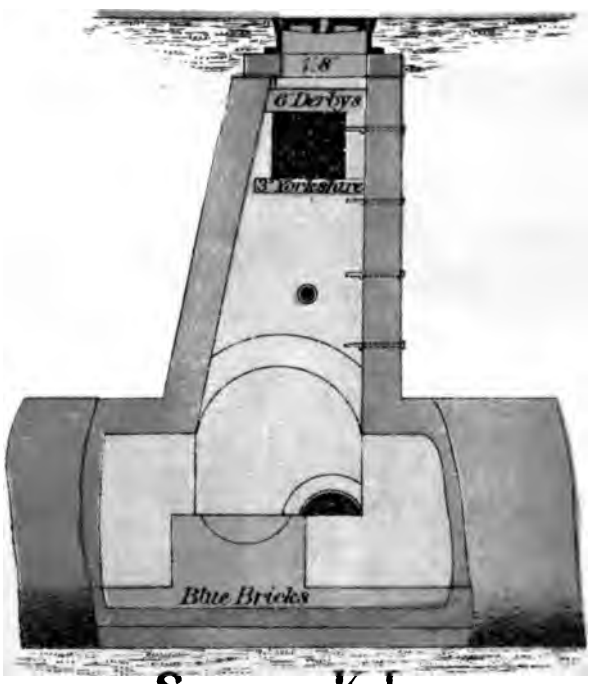
12″ Pipe into 3′. 9″. x 2′. 6″.

Nº 11.





Section I. J.

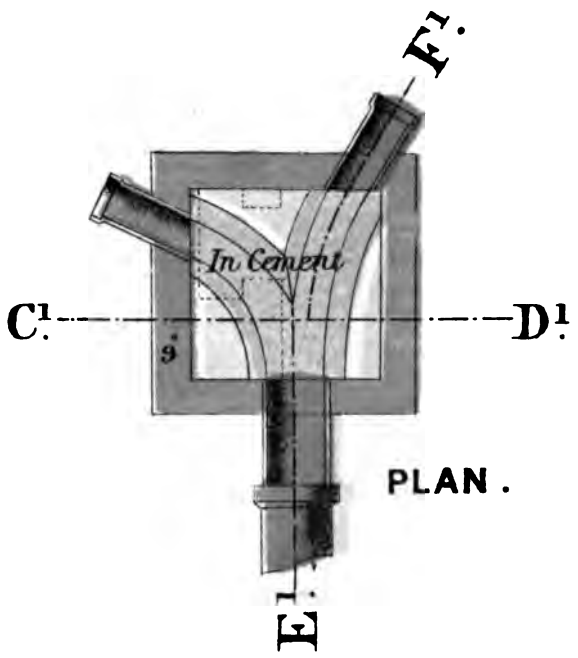


Section K. L.

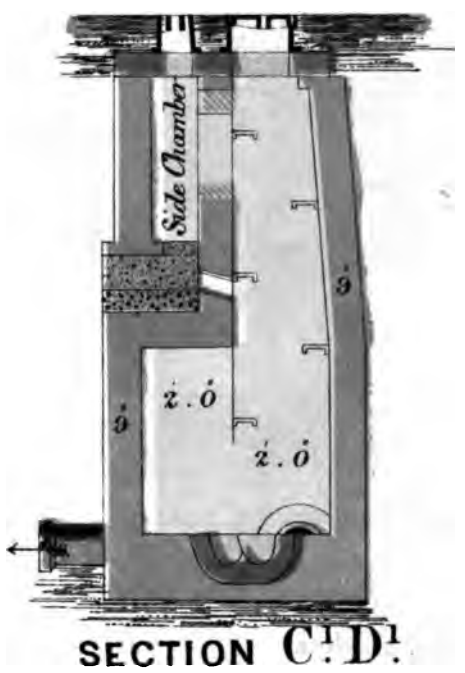
Quarterly by Litt 72 Berners St Corner Cor

No 12.

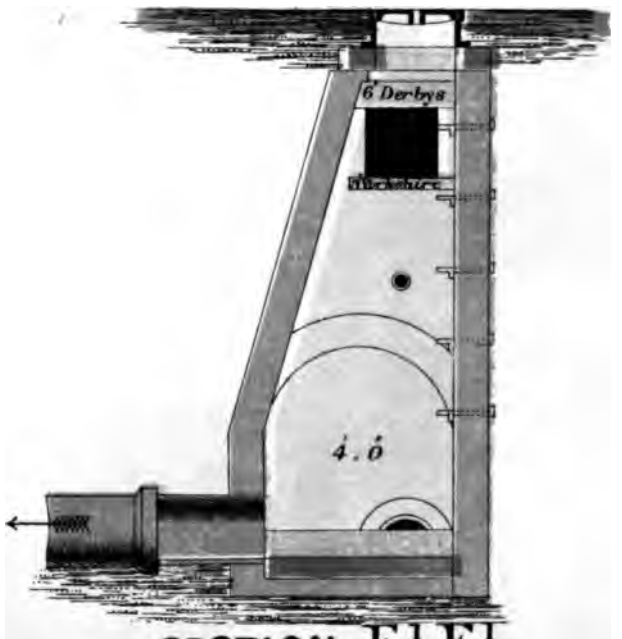
9 Double Pipe into 15 Pipe at end of Sewer.



PLAN.



SECTION C¹ D¹.



SECTION E¹ F¹.

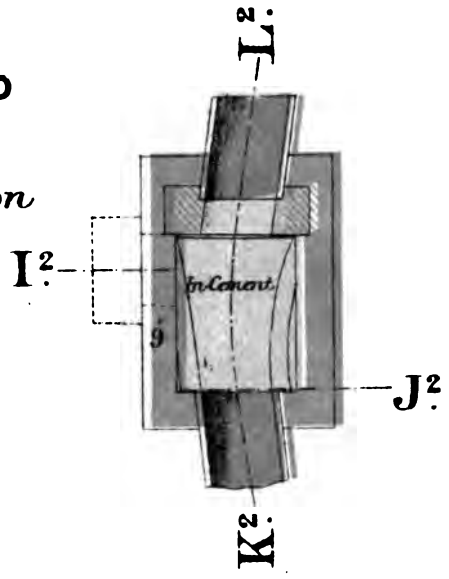
Dangerfield Lith 22 Bedford St Covent Garden.

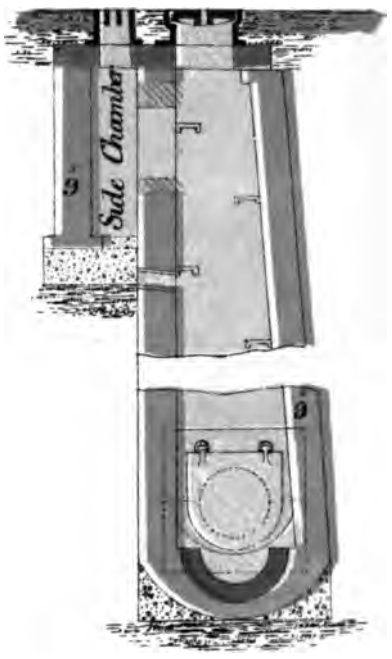
No 13.

VALVE-CHAMBER AND VENTILATION-SHAFT

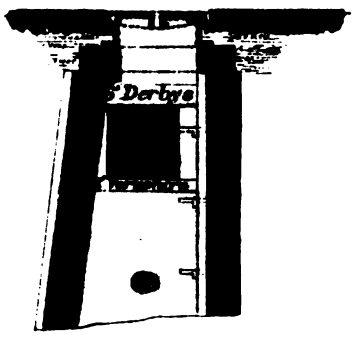
Shewing also change of direction

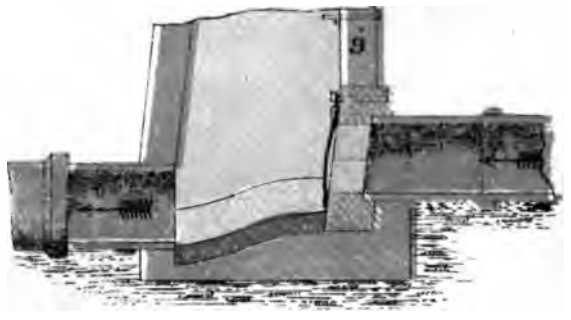
IN MAIN.





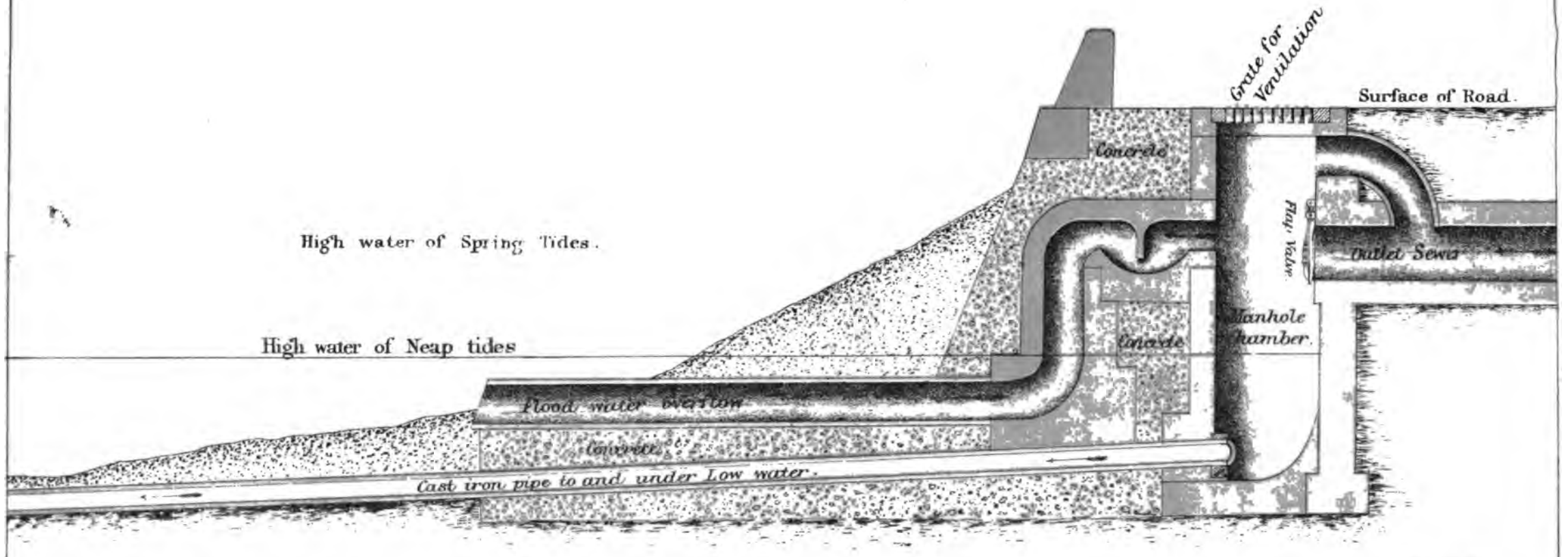
SECTION I². J².





SECTION K². L².

Nº 14.



LONGITUDINAL SECTION OF MAIN-SEWER-OUTLET ON SEA-SHORE

WITH MANHOLE CHAMBER, FLAP-COVER TO MAIN-SEWER, AND VENTILATING-GRATE

THE MAIN-SEWER TO BE FULLY VENTILATED INLAND.

N.B. THIS SECTION IS ONLY INTENDED TO INDICATE HOW SEA OUTLETS MAY BE CONSTRUCTED.

Front Elevation of double hinged flap valve.

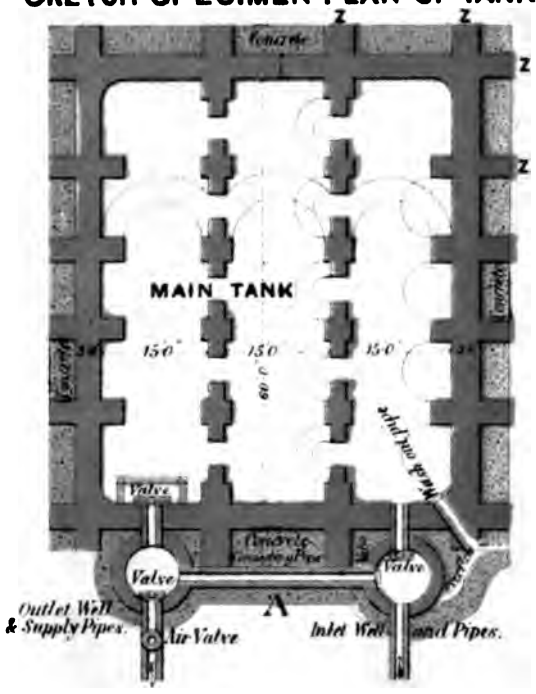
Dangerfield 22 Bedford St Covent Garden

THE SANITARY ACTS.

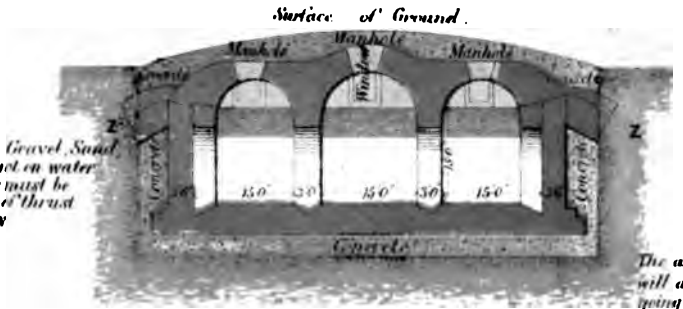
Water Works.

No. 15.

SKETCH SPECIMEN PLAN OF TANK.



CROSS SECTION THROUCH TANK.

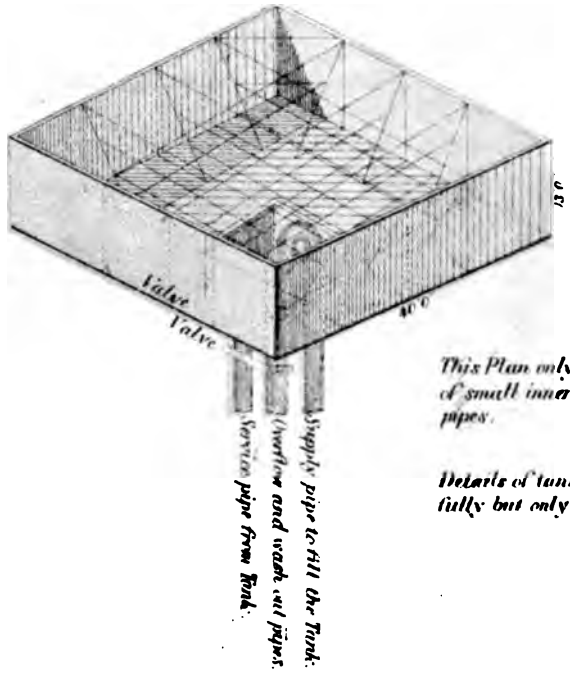


Puddle will be required on Gravel, Sand or on open jointed rock but not on water tight strata. The sidewalls must be securely supported at the line of thrust by main arches as shewn by Transverse at Z.

The arrangement shewn above at A will allow a supply of water going on independent of the main Tank.

The Figures are Feet & Inches.

SKETCH SPECIMEN PLAN OF CAST IRON TANK WITH SEPARATE SUPPLY-CISTERN.



This Plan only shews the general arrangement of small inner Tank with the service and supply pipes.

Details of tank plates and tie rods are not shewn fully but only indicated.

Robert Rawlinson
Civil Engineer.